# Preface

According to the United Nations organization, mountains cover one quarter of the land of this planet, are home to a billion people, and provide over 70% of the freshwater available on land. For these reasons, December 11 has been designated International Mountain Day. Mountains are the essence of mountain cultures and the passion of mountain climbers. Mountains are hence important and, when trying to understand the alpine environment, one realizes that there are both very simple laws of physics at work in the mountains as well as some more complicated ones. Although these laws are basic and fairly easy to understand, their importance is not fully appreciated as easily, though one should not forget them. A little reasoning shows why. These laws have numerous and very important consequences for those who live or travel in mountain terrain. One should be aware of them at all times when one is out there, and must understand the environment and its mutable conditions in order to make critical decisions on which a climber's life — and those of the members of a climbing party — may depend. In more ordinary situations when no drama is involved, seeing and understanding these physical laws in action will just add to the appreciation of the mountain environment. For example, you may be lying down on a well deserved rest after a climb, enjoying the sun and wondering about what lies in front of you. The mountains are steep terrain, often vertical or even overhanging, and on this terrain gravity rules. The dictatorship of gravity is felt by a body hiking up a steep trail or climbing a steep face or a slippery slope on snow or ice. Gravity pulls on the snow which may come down on us as an avalanche when the conditions are right. Gravity pulls on rocks and chunks of ice that have the bad habit of detaching, threatening, and falling on passer-bys. Gravity acts on water that flows as impetuous mountain streams, on slides which erase significant portions of the face of a mountain and obliterate classic climbing routes with or without climbers on them, and on boulders which mysteriously dislodge and roll down a slope. Gravity acts on water rushing down a wall in a thunderstorm, sweeping gullies and small channels and carrying rocks and debris with it, and it acts on snow sloughing off a cliff. Gravity pulls down cornices breaking on mountain ridges and it destroys dicey snow bridges across crevasses. But there isn't only gravity at play: there is a lot of other physics involved in these phenomena and their detailed modelling could keep scientists busy for a long time (in fact, it often does). Not that the mountaineer cares much about physical modelling and its mathematical nuances when caught in dire situations, or panting uphill on a steep slope under a big load, but a little understanding and physical sense can contribute to avoiding bad situations in the first place. An experienced mountaineer has seen many things happening in the hills and has built an understanding of what is going on and the ability to predict what will happen in a certain place under certain conditions, plus the ability to forecast these conditions. Over the years, he or she has built a general sense of the mountain environment and a large part of this understanding is just what physicists call physical sense, applied to the specific mountain environment. There is an innate pleasure in understanding the science related to the mountains and one of the main goals of mountaineering, after all, is maximizing the amount of fun per unit time. It is great to sit on top of a peak and visualizing in thirty seconds the erosion process by glaciers that gave that valley in front of us its U-shape over a few tens of thousands of years. And then we realize that the stripes on those smooth granite slabs on which we are resting were caused by huge ice masses grinding them or, more precisely, by boulders stuck in the ice and acting as a giant file.

Although gravity is dominant, there is much more physics involved in mountaineering, including mechanics, meteorology, hygrometry, fluid mechanics, thermal and statistical physics, electromagnetism, and non-linear physics. There is an enormous range of applications of physics to the natural phenomena encountered in mountaineering: electromagnetism becomes obvious when we are late descending from a climb and we get caught by the afternoon thunderstorm on a summit or along a ridge. Then we wonder what is the preferred path of a lightning bolt, what is the probability of being hit in that particular place, and we would like to know more about ground currents when we stop in a "best place" in thunderstorm position.

The microscopic cohesion forces between snowflakes of a settling snowpack which metamorphose over time are crucial when trying to assess whether to ski a suspicious slope or to back off. The importance of phase changes is perceived when they dislodge rocks above us as the temperature oscillates around zero degrees Celsius. The constant pull of gravity cannot be forgotten when contemplating the effects of erosion, the great destroyer of mountains, for amusement or for trail maintenance. Not that one starts making physics calculations with paper and pencil or that one runs a Monte Carlo computer simulation when caught in a tricky situation, but a little reasoning can help in understanding those situations and making sense of things later, when there is more time to think and to wonder how the events unfolded.

Historically, many of the pioneers of mountaineering in the European Alps and in other areas of the world were trained scientists and, in those early days, the scientific spirit was mixed with the spirit of adventure and discovery [Newby (1977); Davis (2012); Pole (2005, 1991); Worster (2008); Richardi (2008)]. These pioneers often carried heavy instruments to perform scientific measurements on top of the peaks climbed, to determine their elevation, to sketch geographic maps of the area, or for their atmospheric studies. The great Viennese mountaineer Paul Grohmann (1838–1908) who made many first ascents in the Dolomites of Italy (then a part of the Austrian-Hungarian empire) tells tales of how hard it was to climb technical peaks in the Dolomites without breaking his precious barometer, and how he would not let his guides carry it but he would transport the fragile instrument himself [Grohmann (1877)]. The Irish physicist and pioneer mountaineer John Tyndall (1820–1893) mixed physics research and science popularization with mountaineering at a time when both were becoming popular [Reidy (2010)]. It is widely recognized that the development of science and of a scientific attitude pushed the exploration of previously unknown mountains and helped the development of mountaineering in its early stages.

This book examines rather obvious applications of physics to the mountain environment and is written for mountaineers, lovers of mountains, or curious people who wonder why or how this or that natural phenomenon happens, what causes it, and what its scientific explanation may be. This book is not a systematic analysis of the mountain environment and the physics discussion does not go nearly as deep as it could. Indeed, the science of mountain phenomena can quickly become very involved and the research is often open-ended. Sometimes we do not have a clear answer to a scientific question, and that's what makes the subject attractive to researchers in the first place. However, this book is written mostly for non-scientists. While a physics textbook would organize the topics according to the branch of physics to which they belong, I prefer to group the material in categories more relevant for the mountain climber.

It is said that a picture is worth a thousand words. In turn, physicists say that an equation is worth a thousand pictures. Therefore, we will see some formulae and some more technical explanation but, most of the times, these can be skipped without jeopardizing the understanding of the rest. Physical sense is often just plain common sense and mountaineers relate to that. This physical sense, augmented by a little knowledge, is a tool to further the understanding of the mountain environment. This book is not a mountaineering guide and, of course, mountaineering and climbing are not learned from books. As stated on the disclaimers accompanying all the pieces of gear that we buy, there is no substitute for experience, a statement which is reinforced by physicists since physics is an experimental science. This book is not conceived as a preparation for the outdoors, but it is more of a reading after one comes back tired from a mountain trip and has no immediate urge to go back out again, or when the weather is bad and we are stuck at home. A friend of mine even carries such books on multi-day trips to read in the tent in case of rain, which happens all too often in the mountains of coastal British Columbia where he climbs. Some of this book may, after all, turn out to be of some practical use — other than starting a campfire, and I will be happy if it does, but it should not be taken as a practical manual.

Physics and fundamental science in general are seen at work everywhere in nature, but in the mountains we see processes that are much faster or more dramatic than in other situations because of the large gradients involved. It helps to be prepared for the situations that mountains create, to understand them, and to enjoy them as safely as possible.

Those who know some physics will only whet their appetite by reading this book and will probably be mad at its author for not going into some detail. This book provides only glimpses of selected topics in physics and science. It is not possible to make justice to the complexity and variety of physical phenomena encountered in alpine terrain in a short introductory exposition. To be forgiven by those readers, we will see various references that point them to more satisfactory discussions. Finally, the International System of Units (SI system) is used, and the names of my friends appearing in some of the stories of this book have been changed.

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