Chapter II

Introduction to kinetics (statics and impulse theory)

§1. Contrast between continuously acting forces and impact forces; the impulse for a single free mass particle

While in the preceding kinematic chapter we had no occasion to speak of the principles of mechanics, we will have to draw upon these principles in some form for the kinetic considerations that now follow. This can be done in various ways.

The original setting of the principles of mechanics by Newton assumes the concept of force as something immediately acknowledged and understood. More recent presentations often seek to eliminate this concept from the foundations, and introduce it only later as a convenient abbreviated designation in mechanics. The suitability of one or the other procedure depends essentially on the objective that one pursues. If one sets out merely to construct a consistent conceptual system, as Hertz does in his beautiful work on the “Principles of Mechanics,” then one can well dispense with the concept of force. If one wishes, however, to attain a lively comprehension of mechanical phenomena and a rapid orientation in specific questions, as is our intention in these lectures, then the concept of force appears particularly valuable on psychological grounds; namely, this concept is immediately associated with the activities of man, who has in his muscles the possibility of doing work. Such a performance of work is bound in our perception with the feeling of exertion. We involuntarily carry over this perception to the external predecessors of motion as well. The root of the concept of force lies, without doubt, in this anthropomorphic interpretation of external events. We will not, therefore, suppress this interpretation, but rather proceed with this point of view directly in the foreground.\textsuperscript{46}
We determine whether a force acts in a certain direction on a mass particle, which is thought to be fixed somehow in space, by displacing the particle slightly in the opposite direction. If we must perform work (exert our muscles) in doing so, then a force is present; otherwise, the particle is free of force in the given direction. The same procedure can also serve for the measurement of force: we measure a force acting on a particle in a specified direction by the ratio of the work that we must perform in a displacement of the particle in the opposite direction to this displacement \( P = \frac{A}{l} \). If the units of length and work are prescribed, then the unit of force is determined as well.

We have already defined the unit of length on page 11 when we accepted the “absolute system of measurement.” The unit of work is defined in this measurement system, as is well known, by first establishing the unit of mass as the gram, and then referring to experience with freely falling bodies (the so-called law of falling bodies). The unit of work is determined in this way as the 980.60\(^{th}\) part of the work that is performed in the elevation of one gram by one centimeter at the 45\(^{th}\) degree of latitude.\(^{47}\) Work thus receives the dimension \( \frac{ml^2}{l^2} \), and force the dimension \( \frac{ml}{l^2} \). We must certainly declare this definition of the unit of work to be rather indirect from the above psychological point of view. Since force and work lie more immediately in our perception than mass, we could demand that the unit of work be established before the unit of mass, and could advocate the introduction of a general measurement system (which, moreover, is suggested occasionally from other points of view) in which work is used in addition to space and time as the third fundamental dimension. Whether such a measurement system would be recommended practically, we leave here completely undecided.

One traditionally distinguishes, furthermore, two kinds of forces: continuously acting forces and impact or instantaneous forces. The rule given above for the measurement of forces refers, as we must explicitly emphasize, to continuously acting forces. To include the measurement of impact forces, we say that an impact force is equivalent to an extraordinarily large continuous force that acts for only an extraordinarily short time.