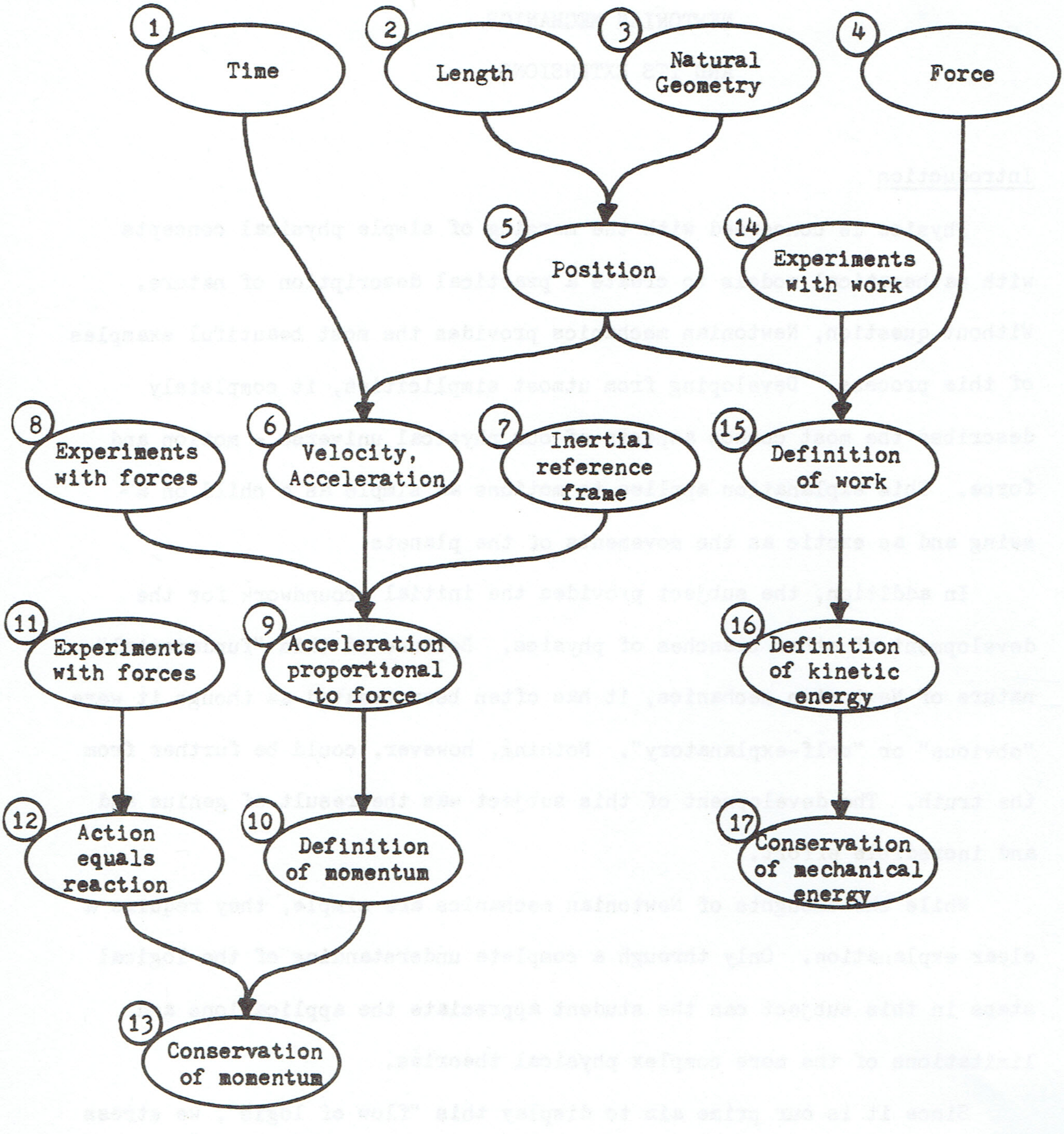
Chart #1

# Newtonian Mechanics



potential energy is a truly meaningful concept. Such a simplicity in nature is just one more reason to be glad this universe is our home!

References to bibliography at end of chapter: 3-7; 5-2; 14-10; 15-24; 16-8; 19-21; 28-3.

## A Final Overview of Newtonian Mechanics

We will now pause and review the development of Newtonian mechanics. Having a familiarity with the individual ideas presented, the student should now be able to better appreciate the way these ideas relate to one another.

Our study began with the mechanical concepts which are basic to human beings - time, length, and force. These are the only mechanical concepts a human being can actually sense; our theory must start here. We discussed the ways in which man can measure these phenomena, and then moved on to discuss concepts which are derived from these basic ones.

To the concept of length in essay #2, we added the geometrical properties of nature which we discussed in essay #3. This enabled us to define the idea of position in a Cartesian co-ordinate reference frame, in essay #5.

We were then in a position to merge the vector concept of position with the concept of time to create two new concepts of motion in essay #6. The first of these was velocity - the rate of change of position; the second was acceleration - the rate of change of velocity.

In essay #7 we discussed Newton's first law of motion: "In the absence of a force, a body will not accelerate." However, this law was incomplete, because position, velocity, and acceleration are meaningful only relative to a specified reference frame. We therefore defined an inertial reference frame as one in which Newton's statement is true. The earth is approximately such a reference frame.

We then considered in essay #8 experimental observations regarding force and acceleration. These experiments, together with the definitions provided by essays #6 and #7, yield Newton's famous second law of motion. This law, (explained in essay #9), states that in an inertial reference frame an object's acceleration is directly proportional to the force applied to it, and inversely proportional to the "amount of matter" in the object. In fact, since the acceleration of an object and the force applied to it can be readily measured, Newton's second law serves as a definition of "amount of matter". We call this quantity the inertial mass of an object, and it is proportional to the weight of the object on the surface of the earth.

In essay #10, we defined a quantity which was useful because of Newton's second law of motion. This was momentum - the product of the inertial mass of an object and its velocity. Momentum was intuitively meaningful because it indicated a "quantity of motion". More importantly, however, the second law of motion shows us that the product of force and time is equal to the change of momentum of an object. This fact was to be used in essay #13.

Before the discussion of momentum in essay #13, we mentioned more experimental evidence, and the resulting third law of motion described in essay #12. This law states a very simple observation of force: "Whenever one object exerts a force on a second object, the second object exerts a force on the first. The two forces are equal and opposite".

Now this law of motion is in itself important, but when combined with the concept of momentum it results in one of the most universal laws of nature - the conservation of momentum, discussed in essay #13. This law states that the sum of the momenta of the objects in an isolated system will remain constant, dispite any internal events which may occur. The advantage of this law is that it makes over-all conclusions which are independent of the specific occurances in a system.

Our study then moved on to deal with the nebulous concepts of energy. In essay #14 we introduced various phenomena which we consider to be energy - heat, light, sound, electricity, and mechanical energy. For the purposes of Newtonian mechanics, we sought only to discuss mechanical energy - and we planned to do this by studying mechanical work - the conversion of one form of energy into mechanical energy. Certain experimental observations suggested a simple measure for work.

In essay #15 we stated the definition of mechanical work - the product of force exerted on an object, and the distance the object moves in the direction of that force. Now work indicated a conversion of one form of energy into another; associated with a quantity of work there was always an increase of some sort of energy. In essay #16 we imagined a situation where work was performed on an object, and the only form of energy which could increase was the kinetic energy of the object (the energy of motion).

This lead to our formula for the kinetic energy of a moving object:

$$E_k = \frac{1}{2}mv^2$$

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This is really the first form of energy we defined; all other energies are so termed because they are capable of being converted into kinetic energy and back. These conversions occur in a precise proportion, and are really the only way of defining other forms of energy.

In essay #17 we used this idea to define the other form of mechanical energy - potential energy. We observed that there are many closed systems where the total kinetic energy will decrease, only to return at a later time. We found that if we assumed the kinetic energy was "stored" in another form of energy, potential energy, then this potential energy depended only on the physical state of the system. The idea of potential energy is described by the so-called "law of conservation of mechanical energy". This law states that in a system without friction, the sum of the kinetic energy and potential energy remains constant. This law is a useful way of defining potential energy; its real importance is that it states potential energy can be defined in this way without contradiction.

The ideas of Newtonian mechanics have resulted in useful ways of predicting the motion of a single object. More importantly, however, they have resulted in two very useful statements regarding the over-all nature of a system. The first of these was conservation of momentum, the second was the conservation of mechanical energy in non-frictional systems. These ideas are incredibly versatile in making simple predictions regarding complex systems.

The subject of Newtonian mechanics is the foundation of all physics. It leads to the study of thermodynamics, and sets the stage for the extension of mechanics to the high speeds of special relativity. These ideas together are used in describing nature in the unseen realm of the atom, and the sum of physical knowledge can describe the basic mechanisms of chemistry and biology. Clearly, Isaac Newton opened a Pandora's box of physical explanations.

In the following appendix to Newtonian mechanics, we will discuss a few of the immediate consequences of the subject. While they will be very useful later on, we will only discuss them briefly, for they do not greatly contribute to our study of the evolution of ideas. They are the applications of Newtonian mechanics which set the stage for future consideration of the matter and energy which form our universe.