Chapter 9: Apparent Forces

~Forces due to relative and non-relative acceleration~

When you're in a car and it accelerates, you feel your body being pressed against the seat. This kind of force is called an apparent force, and centrifugal force and Coriolis force are also said to be examples of this force. The reason this force is called apparent is that it appears depending on how the coordinates are chosen, and it is called apparent because it does not actually exist.

If forces have apparent properties, then there must also be real, existing forces. What are real forces? For example, the force of pulling a string is said to be a real force. If so, then if you attach a string to a ball and spin it around, the tension in the string is a real force. However, this force is also centrifugal force. If centrifugal force is an apparent force, then this tension in the string must also be considered an apparent force.

Ultimately, we must conclude that the difference between apparent force and real force is not clearly defined even in modern physics. This distinction between apparent and real force is a crucial topic at the heart of physics and should never be taken lightly. For example, if someone punches you, if that force is an apparent force, the person who punched you is not at fault, but if it is a real force, it constitutes assault.

This chapter clarifies the difference between apparent forces and real forces. The conclusions reached in this chapter may provide one answer to the "Newton-Mach bucket thought experiment" that has long puzzled physicists.

9.1 What is explained as an apparent force

What is apparent power? It is generally explained as follows:

> "When there is a coordinate system with acceleration 'a' relative to an inertial frame of reference, a force must be added to incorporate the effect of acceleration 'a' when setting up Newton's equations of motion in this coordinate system. This force is introduced as a result of the coordinate transformation and is not a real external force acting on an object, so it is called an apparent force. This force is also called the inertial force, and the Coriolis force and centrifugal force are types of this force."

In this explanation, real forces are referred to as "real forces acting on objects." Conversely, this implies that apparent forces are not these real forces. This would mean that centrifugal force does not act on objects, but this is absolutely not the case. Centrifugal force also acts on objects, which is precisely why inventions like centrifuges exist. The explanation of apparent forces given here contains an internal contradiction and cannot be considered a correct proposition. This is likely due to the ambiguity and confusion between what we call apparent forces and what we call real forces.

It is impossible to correctly explain apparent forces because they are confused with real forces. This is because apparent forces can be considered to be "defined" in the way described here. Therefore, what is required of us is to redefine the concept of apparent forces by discovering the characteristics of such phenomena. First, we must begin by discovering the characteristics of the phenomenon.

Although the explanation of apparent force given earlier was rejected overall, the first part of it is not particularly incorrect. (The concept of force here is certainly unclear.) Therefore, apparent force is,

"When there is a coordinate system with acceleration a relative to an inertial frame of reference, the force that must be added to incorporate the effect of acceleration a when setting up Newton's equations of motion in this coordinate system."

Let's interpret it that way for now.

9.2 The concept of apparent velocity

The word "appearance" sounds somewhat spooky, and seems like a word that should never be used in physics. I want to clarify what kind of things the word "appearance" is used to describe.

If force has an apparent function, then velocity must also have an apparent function. Force can be considered a function of the time change of velocity, and if the mass in question is constant, then force can be considered a dependent function of velocity. If we write about velocity in the same way as we interpreted the proposition, then apparent velocity is:

"When there is a coordinate system with velocity v relative to an inertial frame of reference, the velocity that should be added to incorporate the effect of velocity v when setting up Newton's equations of motion (equations of momentum) in this coordinate system."

This would be the case. Such an example is that, from the perspective of a moving train, the station can be considered to be moving in the opposite direction to the train's speed, and this way of thinking is certainly possible. In this case, it is clear that the velocity v in question is identical to the concept known as relative velocity. From this, it can be considered that the meaning of the word "apparent" as used in physics can be replaced with the meaning of "relative."

9.3 Terminology related to appearance

Let's redefine the physics terms we've used so far, assuming that the meaning of "apparent" can be replaced with "relative."

Apparent velocity is relative velocity (9.1)

Apparent momentum is relative momentum = mass × relative velocity (9.2)

Apparent acceleration is relative acceleration = time derivative of relative velocity (9.3)

Apparent force is relative force = mass × relative acceleration (9.4)

Relative force, which is a force based on relative acceleration, cannot actually push any object. The concept of apparent force, which has been used until now, includes real forces, but here we will define relative force as a force that clearly excludes real forces from apparent force. Later we will identify the real forces that are confused with apparent forces, but we define the concept of relative force as a new term to distinguish them.

In what will be discussed from now, when the expression "apparent force" is used, it refers to the "apparent force" in the old sense, as understood in existing knowledge of physics. The "apparent force" redefined here will be called a relative force and will be distinguished from it.

9.4 Existing knowledge of physics cannot describe real forces.

According to existing knowledge of physics, the force that pushes you down when you're in an accelerating car, centrifugal force, and even gravity are considered apparent forces. So what kind of force is a real force? Existing knowledge of physics cannot physically describe this real force. This is because existing knowledge of physics assumes that all velocities are relative velocities, and therefore all accelerations, which are the time derivatives of velocities, must be considered relative accelerations. Relative acceleration is an apparent acceleration, and any force expressed using this concept must be a relative force. The conclusion reached

using existing knowledge of physics is that all forces are relative forces.

9.5 What is velocity that is not apparent?

While existing knowledge of physics cannot describe real forces, let's consider velocity, which seems to be a simpler concept, before dealing with acceleration related to forces.

I considered apparent velocity to be the same as relative velocity, but is there a concept of velocity other than relative? If all velocities are relative, then there would be no such thing as real velocity.

The generally defined concept of velocity is based on relative velocity with respect to a coordinate system, and is essentially no different from relative velocity. Using this type of velocity, it becomes impossible to represent actual velocity.

A new way of expressing speed is required.

From the perspective of a moving train, the station appears to be moving in the opposite direction. In this case, the dynamics of the station as seen from the train can be correctly predicted by assuming that the station has an apparent velocity (= relative velocity). For example, the position of the station as seen from the train a few minutes later can be predicted. From the perspective of relative motion, the station and the train are treated as completely equivalent. Nevertheless, no one thinks that the station is moving. Why do we know this? Why do we think that it is the train that is moving and not the station? Because there is a clear difference.

The amount of motion of the train as seen from the station

$$\text{Momentum of a train} = \text{Mass of the train} \times \text{Velocity}$$

That's how it works. Conversely, the momentum of the station (space?) as seen from the train is...

$$\text{Momentum of a station} = \text{Mass of the station} \times \text{Velocity}$$

This can be considered. If we only have relative velocity, then we must also acknowledge momentum. Is it possible to extract the

energy of momentum from this station? In terms of kinetic energy, we can consider that it is the train that possesses kinetic energy, not the station, and thus we can see the difference that it is the train that is moving, not the station. This difference cannot be expressed by relative velocity, and the equation momentum = mass × velocity is insufficient in terms of recognizing the concept of velocity.

The speed at which it can be expressed that what is moving is a train, not a station, is considered to be the actual speed. And the differences mentioned here are one piece of evidence that such speeds exist.

In Chapter 2, we discovered the concept of inertial velocity. Using this concept, we can clearly express that it is the train that is moving, not the station. This velocity is considered to be the actual velocity, not an apparent (relative) velocity.

The idea that "the laws of various physical phenomena are the same for a stationary observer and for an observer undergoing uniform parallel translation" is clearly incorrect, as explained in Chapters 4 and 5. This is because the physical phenomenon of inertial velocity is not the same for a stationary observer and for an observer undergoing uniform parallel translation.

9.6 The concept of real forces

What exactly is a real force? We have called real velocity inertia. Newton's equations of motion are thought to reflect this real force, and according to their description, real force = mass × time derivative of real velocity. Considering this correspondence, let us redefine the relevant terminology.

Real velocity is inertial velocity (9.5)

Real momentum is inertial momentum = mass × inertial velocity (9.6)

Real acceleration is inertial acceleration = time derivative of inertial velocity (9.7)

Real force is inertial force = mass × inertial acceleration (9.8)

The term "inertial force" has, until now, been treated as a type of apparent force or as a force in itself. The "inertial force" redefined here is entirely different from such an ambiguous concept. If

possible, to avoid confusion, we would prefer not to use the term "inertial force" as a term with a new physical meaning, but this way of referring to it is considered most appropriate to concisely show the meaning of this force, so we will use it this way. The meaning of the word "inertial force" as it has been used conventionally is the apparent force that pushes you back into your seat when riding in an accelerating car, but we will not use the word "inertial force" in this sense. However, from now on, to avoid confusion, we will refer to the "inertial force" redefined here as a "real force."

9.7 Forces associated with acceleration

Now, let's finally delve into the main topic of this chapter: the concept of "apparent forces."

Let's assume there is an elevator in outer space. Let's assume there are no external forces such as gravity, and that the inside of this elevator is an inertial coordinate system. An apple is floating in the center of the elevator, and at this point, the relative velocity between the elevator and the apple is zero, so let's assume the apple is at rest relative to the elevator.

If you pull on an elevator in some way, it will appear as if a force is acting on the apple from the elevator's perspective. This is a relative force caused by the relative acceleration between the elevator and the apple, and is what is known as an "apparent force."

The apple will eventually hit the elevator wall. At this point, a force will be generated between the apple and the wall, and this force is of the same kind as the force that presses a person against their seat in an accelerating car. Is this force a relative force, an "apparent force"? If this force is a relative force, then we must also acknowledge that the interaction when two spheres collide and are bounced apart is also a relative force, an "apparent force".

In this thought experiment, the apple doesn't necessarily need to be inside the elevator; the result would be the same even if it were outside. It's simply a collision between two objects. It's essentially no different from a white ball and a black ball, where the

white ball is accelerating and collides with the stationary black ball. Before the white ball collides with the black ball, from the white ball's perspective, a force corresponding to the relative acceleration appears to be acting on the black ball. Eventually, when the white ball collides with the black ball, the white ball pushes the black ball, and the black ball pushes the white ball back in reaction. It's clear that the force the black ball exerts in reaction to push the white ball is of the same kind as the force that presses a person against the seat of an accelerating car. The force that presses a person against the seat of a car doesn't need to be distinguished from a force in the ordinary sense; such a force can be considered a real force. The difference between the black ball before it hits the white ball and the moment after the collision is whether the black ball actually moved or not; in other words, the difference is whether its inertial velocity changed or not.

The previously accepted concept of "apparent force" failed to recognize this difference and confused relative force with real force.

9.8 The difference between relative and inertia

Let's summarize the difference between relative and inertia here.

(1) The motion of the object in question

Concepts such as relative velocity and relative force do not, or cannot, consider whether the object in question is actually moving or not. Movement, in this context, refers to movement relative to a redefined inertial coordinate system.

In contrast, inertial velocity and real-world forces are concepts that deal with, or can deal with, whether or not an object is actually moving relative to an inertial coordinate system.

(2) Expression of momentum (energy)

Even if an object in question possesses relative momentum due to its relative velocity, it is not possible to extract energy equivalent

to that relative momentum by changing its relative velocity. In other words, no matter what coordinate system manipulation is performed, it is not possible to actually move an object. To change real momentum, a change in inertial velocity is necessary. That is, a force that changes inertial momentum is a real force, while a force that cannot change inertial momentum is a relative force.

(3) Forces accompanied by reaction

Related to (2), relative forces do not have a reaction force. If we disregard the effect of gravity, a force is real when there is a reaction force, and a relative force when there is no reaction force.

9.9 Forces associated with rotation

It is said that centrifugal force and Coriolis force are "apparent forces" associated with rotation. However, there are relative centrifugal forces and actual centrifugal forces, and these are often confused, similar to the forces associated with acceleration in section 9.7.

Let's call the relative centrifugal force the relative centrifugal force, the centrifugal force as a real force the inertial centrifugal force, the relative Coriolis force the relative Coriolis force, and the Coriolis force as a real force the inertial Coriolis force.

As mentioned at the beginning, the centrifugal force generated when an object rotates does work and cannot be considered equivalent to a relative force that does no work. On the other hand, if we consider that a centrifugal force acts on an object with zero relative velocity to this coordinate system from the perspective of an actually rotating coordinate system, we can correctly predict its position, just as with relative forces. While it is possible to think in this way, from the perspective of a relatively rotating coordinate system, surrounding objects are not pushed outwards. If it were possible to exert an effect similar to inertial centrifugal force on an object by rotating the observation coordinate without actually rotating the object, then spectators watching a figure skater spinning would have to be pushed outwards from the skater's perspective.

When discussing rotational motion, there are two types of rotation: relative rotation, which corresponds to relative velocity, and inertial rotation, which corresponds to inertial velocity. These must be treated separately, just as with the force associated with acceleration in 9.7. To explain this in the same way as with velocity, relative rotation does not consider, or cannot consider, whether the object in question is rotating or not. In contrast, inertial rotation considers, or can consider, whether the object in question is rotating or not.

Inertial rotational motion is a distortion of uniform linear motion, therefore, a real force must exist. In relative rotational motion, there is no effect that alters the motion of the object. In other words, the existence of centrifugal inertia associated with rotation is not a relative concept; even if there is only one object in the universe, it is possible to consider its rotation, just as with inertial velocity, and its centrifugal inertia is also considered to exist.

In Mach's "bucket thought experiment," it seems he reasoned that "if there is nothing else to compare it to in the universe, then there is no point in rotating it. Even if you rotate the bucket, there is no centrifugal force and the surface of the water in the bucket does not change. Since all motion is relative, no one can tell whether it is rotating or not." I believe it is already clear that this way of thinking is wrong. The surface of the water in the bucket is indented because the inertial velocity of the water is changing, and inertial velocity is not a relative concept.

Mach's explanation of the actual centrifugal force is as follows: "From the perspective of a rotating coordinate system, the universe rotates in the opposite direction. Therefore, centrifugal force arises from some gravitational effect exerted by the mass distributed in the universe."

If this idea were valid, then the force that arises from the collision of two spheres must also be considered some kind of gravitational force existing in the universe. This is because, not only for rotational motion, but even for a sphere moving in a straight line, if we fix the coordinates to it, the universe can be considered to be moving in the opposite direction. We believe that this idea is not worth seriously evaluating, but let us show that even with respect to rotation, the concept of relative force cannot explain centrifugal inertia.

First, let's assume that two disks A and B, sharing the same axis, are at rest in an inertial coordinate system. Next, let's assume that only disk A is rotated at a constant rotational speed v. From a coordinate system based on A, B appears to be rotating at the same rotational speed v, and from a coordinate system based on B, A appears to be rotating at the same rotational speed v. The relative rotational speeds as seen from the coordinate systems of A and B are exactly equal and indistinguishable. If the object being observed is B for A and only A for B, then using the concept of relative rotational speed, it would be impossible to distinguish which is rotating. However, if accelerometers were installed on disks A and B, it would be found that acceleration is observed only on A and not on B. In other words, it can be seen that the centrifugal force of inertia exists on A and not on B. This can be easily demonstrated experimentally.

Or, A, B If you rotate them in opposite directions, If it is the universe, not A and B, that is rotating, then in which direction should the universe rotate?

Furthermore, from the perspective of the sun, the Earth revolves around the sun, but conversely, from the perspective of Earth, we can observe that the sun revolves around the Earth. If all motion is relative, then it is perfectly correct to think that the sun revolves around the Earth. However, if we think this way and apply the law of universal gravitation to the motion between the sun and the Earth, the sun will appear to be moving further and further away from Earth.

If the law of universal gravitation is correct, then the idea that all motion is relative is incorrect, and if the idea that all motion is relative is correct, then the law of universal gravitation is incorrect. Any physicist should know this. Yet they insist that both the idea that all motion is relative and the law of universal gravitation are correct. Physicists who affirm the idea that all motion is relative do not understand at all why Galileo worked so hard. If we observe from a coordinate system based on Earth, the universe will be moving around Earth. This idea is what is called the geocentric model, but the idea that all motion is relative does not negate the geocentric model, and therefore affirms it. Even today, the geocentric model survives as the mainstream of physics, but

physicists who support this theory think that they do not support the geocentric model.

Kinetic energy, which represents the energy of inertia, is proportional to mass.Since mass is the source of gravity, the idea that centrifugal force and inertial forces are some kind of gravitational action seems correct. However, it would be incorrect to consider them as gravitational forces from an external source (space), as Mach suggested. Since the effect depends on the object's own mass, it should be considered as something caused by the object's own mass.