Abstract. We developed a three-dimensional (3D) virtual simulation with tablet devices, suitable for beginning students to learn about mechanics. On our simulation, when a force is applied to a virtual object, the object moves in the 3D virtual space without any friction. Students can experience this frictionless motion virtually. The experience is expected to correct students’ misconceptions concerning fundamental physics.

1. Introduction
Clement showed that the difficulty of understanding mechanics originated from a preconception that continuing motion implies the presence of a continuing force in the same direction as the motion [1]. He called this preconception the “motion implies a force” (MIF) misconception. Many Japanese high-school students reportedly have this MIF misconception [2]. Several methods have attempted to correct the MIF misconception, such as monitoring metacognition [3], and an error-based simulation [4]. These methods are trying to correct the students’ misconception by noticing the scientific error in the MIF misconception. However, it has been difficult to correct this misconception [5].

Clement pointed out that the MIF misconception is formed by the friction between objects, which exists in every situation in the real world [1]. Because it is difficult for students to consider energy loss occurring via friction, many students think that applying the force is necessary to keep the object moving. Therefore, the experience of frictionless motion might help to correct the MIF misconception; however, frictionless motion is not easy to experience in the real world.

In this study, we developed a frictionless virtual simulation with tablet devices. Although, a simulation, which works on conventional PCs, has already been developed [6], a simulation, which can be controlled with a touch panel, has not yet been developed. If the frictionless virtual simulation can be experienced on the tablet device, it will be easy to use in physics classes because the tablet device is becoming widespread in education as the information and communication technology device.

2. Development of the simulation
The application was developed for Android devices using Unity 2018. In the Unity, various physical parameters can be controlled using a physics engine, which is called PhysX.

The development concept of this application is as follows. Users can apply the force to a familiar object as shown in Fig. 1, and see the motion of the object. Furthermore, users can change the physical parameters such as friction, gravity and elastic collision, and they can tell how the motion is changed. Details of the application will describe in the following sections: the viewpoint and operation method of the player (section 2.1), the method for applying force (section 2.2), the physical parameters such as friction (section 2.3), and the prepared scenes (section 2.4).
2.1 User viewpoint and operation

There are two user viewpoints: one is the objective viewpoint, shown in Fig. 2 (a), and the other is the subjective viewpoint, shown in Fig. 2 (b). In this application, we adopted the latter viewpoint to allow users to secure a more realistic feeling.

Using the swipe, pinch, and tap actions and the buttons of Fig. 1 (b) and (c), the position and direction of the user viewpoint can be changed, intuitively. By pressing the “Help” button [Fig. 1 (a)], a help manual for the operation method appears, as shown in Fig. 3.
2.2 Force applying method

A target marker was set to determine the point of action in the virtual space. In Fig. 1(d), a chair with a mass of 3.0 kg is selected as the target. The force in the x-y plane can be applied by dragging the target marker, and long press the marker can apply the force in z-direction. Fig. 4 shows two screenshots: just after a force is applied to the virtual chair (a), and (b) shows after a while that the force is applied. When the force is applied, the direction and magnitude of the force are shown are shown as a pink segment (a).

2.3 Friction and other parameter settings

To control the coefficient of friction, a checkbox is set at the upper right of the screen, shown in Fig. 1 (e). When the box “F = 0” is checked, the coefficients of static and dynamic friction in the physics engine become zero. Users can easily experience a frictionless virtual world.

As shown in Fig. 1(f), users also can experience zero gravity and perfectly elastic collision by checking “G = 0” and “R = 0,” respectively. When these boxes are left unchecked, the initial parameter settings are set as 0.6 for the coefficient of dynamic friction, 0.8 for the coefficient of static friction, 9.8 m/s$^2$ for gravity, and 0.3 for the coefficient of restitution. Details of these parameters can be changed in an advanced mode, shown in Fig. 5.
Fig. 5. Advanced mode. Each parameter can be freely changed.

### 2.4 Scene selection

The scene selection page is called when "Scene" button is pressed [Fig. 1 (g)]. Twelve different scenes, such as Domino and Billiards, were prepared for physics simulations (Fig. 6).

Fig. 6. Twelve scenes for virtual mechanics simulations

### 3. Discussion

The MIF misconception is formed in daily experience, where the coefficient of friction is non-zero. Using the developed virtual simulation, students can compare physical situations between the real and virtual worlds without any friction. We expect that this simulation will help students in acquiring the concept of fundamental physics. We plan to apply this simulation in high-school physics classes, and will verify the efficacy.
4. Conclusion

We developed a 3D virtual simulation for beginning students to learn mechanics with the tablet device. By experiencing frictionless motion in virtual reality, students’ MIF misconception is could be corrected.

Acknowledgements

This work was supported by JSPS KAKENHI Grant Number JP17K04844.

References


