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Doubts and Amendments to Newton's Third Law

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Abstract

This article first raises the doubts that scholars have about Newton's third law, particularly pointed out Newton did not clarify the perspectives of "action" and "reaction" in the third law; do these two words really mean "force" and whether the object in "action" or "reaction" will move. The main purpose of this article is to rectify the third law, and then apply the rectified third law to explain three common cases in physics with the help of free body diagram.

Keywords: Newton's third law, reaction force, action force, gear

1. Introduction

Feynman Lecture of Physics Volume I has stated: "──Newton also gave one rule about the force: that the forces between interacting bodies are equal and opposite—action equals reaction; that rule, it turns out, is not exactly true. ──"**[1]**

Rhett Allain (2013) has pointed out: " ──Let me make something clear. Isaac Newton had it tough. Here he is trying to make a model that describes what forces do to objects. However, he just doesn't have all the words we have - like momentum, acceleration, velocity. Fortunately, there is an online translation of the original works of Newton. Here is an older translation into English of Newton's The Mathematical Principles of Natural Philosophy (volume 1).The part about the Third Law says:*To every action there is always opposed an equal reaction: or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.*He also writes:*If you press a stone with your finger, the finger is also pressed by the stone.* This above example could indicate that he did not mean the stone and the finger have to move. I would suggest that perhaps Newton meant the word "action" to really mean "force". However, he later uses the word force so I'm not exactly sure of his intentions. Perhaps by "action" he means a force that actually does something. I don't know. Oh, and it seems Newton does use the words momentum and velocity (if you read more of the passage). Maybe he was just trying to be poetic with his use of the words "action" and "reaction".──" **[2]**

To be exact, the third law is a force transmission principle-applied to objects that are in contact and are relatively stationary, the action force and reaction force between two interacting objects are always equal in magnitude, opposite in direction, and acting on the same straight line.In the equilibrium condition of rigid body in University's year1 statics, the third law is used to create the free body diagram. But, how is the model of the rigid body in motion?

2. Example of Models Built According to Rectified Third Law

The following sections used three study cases for discussion on the rectified third law.

2.1 The object is in contact and relatively stationary with the ground

The object in *Figure 1* is relatively stationary with the ground.

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In the X-axis direction, based on the rectified third law, the force exerted by your finger on the object is finally transmitted to the ground.In the Y axis direction, the gravity force acted on the object is in same direction with the force exerted by the object on the ground; therefore, the magnitude of gravity force acted on the object is equal to the magnitude of the reaction force exerted on the object by the ground.

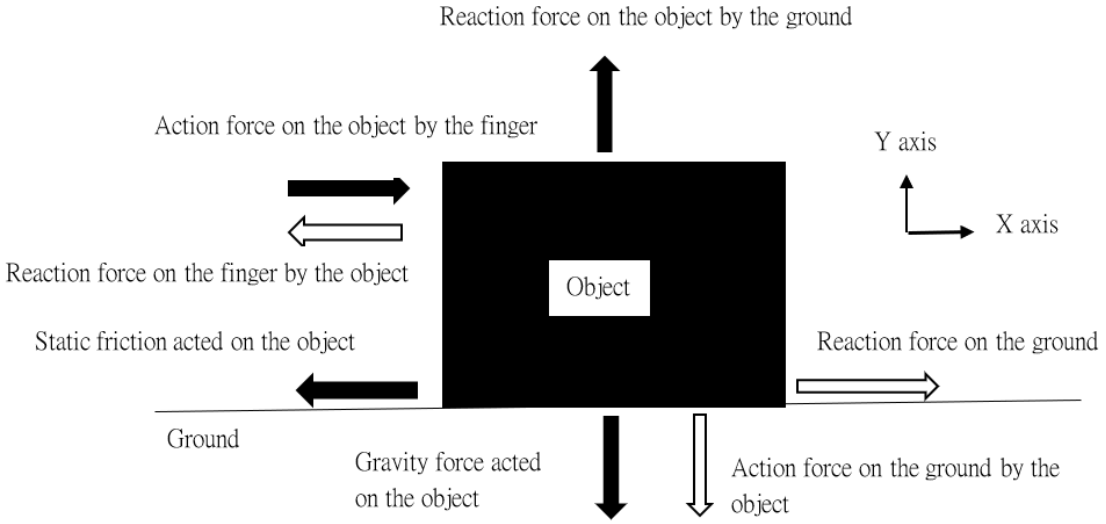

***Figure 1**: the object is in contact and relatively stationary with the ground*

2.2.The object is in contact and moves relative to the ground

The object in *Figure 2* moves relative to the ground.

In the X-axis direction, if the force exerted by your finger on the object is equal to the reaction force on the finger, then the force exerted by your finger on the object is simply used to resist the friction; the object will move at a constant speed.The force exerted by the finger on the object is finally converted into heat energy. If the force exerted by your fingeron the object is greater than the dynamic friction, the object then will has an acceleration and the reaction force exerted on the finger is equal to the dynamic friction.

In the Y axis direction, the object is relatively stationary to the groundregardless of the object is moving at a constant speed or in acceleration. The gravity force acted on the object is in same direction with the force exerted by the object on the ground; therefore, the magnitude of gravity force acted on the object is equal to the magnitude of the reaction force exerted on the object by the ground.

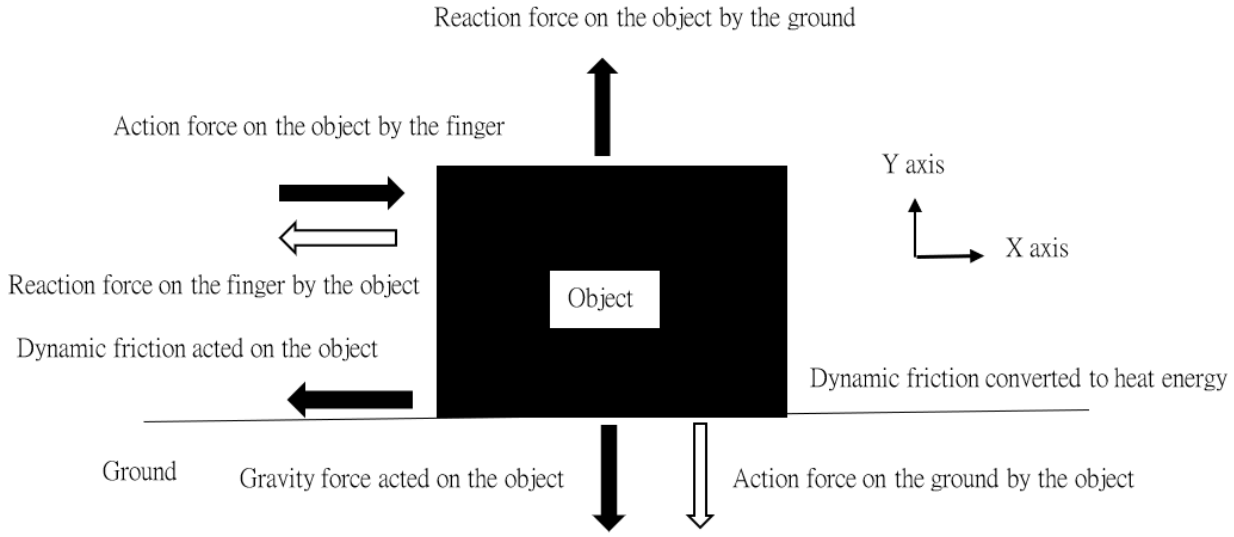

Figure 2. *the object is in contact and moves relatives to the ground*

2.3. Two contacted rotating cylinders

Now let's look at the force transmission model of two contacted rotating cylinders;that is, the force transmission mechanism of gears.Figure 3 below is taken from "Dynamics of Planetary Gear Sets".**[3]**.Point of contact between cylinder **A** and cylinder **B** is relatively stationary.Cylinder **A** exerts$\mathbf{F_{tr}}$ to cylinder **B** at the contact point. The action force and reaction force of the third law only appear in the radialdirection of the cylinders.The tangent force, $\mathbf{F_t}$ causes the cylinder **B** to rotate, we can set $\mathbf{F_{tr}}$ equals to $\mathbf{F_t}$ because $\boldsymbol{\Theta}$is very small.The radius of cylinder A is $\mathbf{R_A}$, and the radius of cylinder **B** is $\mathbf{R_B}$.

$$\boldsymbol{Torqueratio} = \frac{F_{tr} \cdot R_B}{F_{tr} \cdot R_A}$$

$$= \frac{R_B}{R_A}$$

Velocity ratio is the reciprocal of torque ratio.

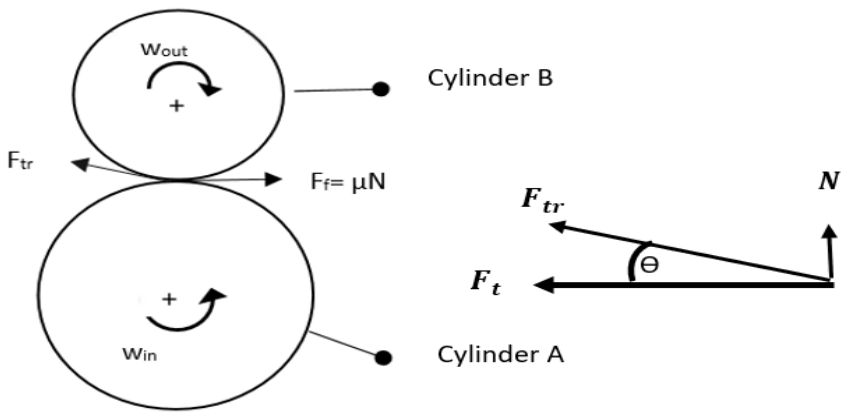

Figure 3. two contacted rotating cylinders

3. Conclusion

The rectified third law: "A force transmission principle-applied to objects that are in contact and are relatively stationary, the action force and reaction force between two interacting objects are always equal in magnitude, opposite in direction, and acting on the same straight line." Or put it in simple: an object A exerts a force on object B but does not cause object B moves relative to object A;then the object B will exert a force in the opposite direction but the same magnitude on the object A.

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