Investigation of dynamical problems by the concept of the system

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Abstract

In this paper we show the new understanding of the Newton's second law, concept of the system leads to both a new interpretation of Newton's second law and a new method in solving dynamical problems. We believe that reading this paper introduces new precise attitude to dynamics.

Keywords: System, dynamic problem, Newton's second law.

Resumen

En este trabajo se muestra la nueva comprensión de la segunda ley de Newton, el concepto del sistema lleva una nueva interpretación de la segunda ley de Newton y un nuevo método en la resolución de problemas dinámicos. Creemos que la lectura de este trabajo nos introduce una nueva actitud precisa de la dinámica.

Palabras clave: Sistema, problema dinámico, segunda ley de Newton.

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I. INTRODUCTION

Isaac Newton (1642-1727) presented his three laws of motion in 1687 in his Philosophiae Naturalis Principia Mathematica, usually called the Principia. In the century following Newton's statement of his celebrated laws, physicists and philosophers debated whether force was a primary concept or a mere aid in calculations[1]. Indeed the Newton discovery was not that force equals to the product of its mass and its acceleration, because this expression in only definition of force. Newton discovered that physics laws by the concept of force with this method of definition are expressed easier. In this paper our aim is to offer a new attitude to dynamical problems by the particular concept of system and examples. First we want to describe Newton's second law from a new point of view. Then we will introduce the concept of the system In Newton's second law using several examples.

II. METHOD

As you know the fundamental equation of classical mechanics is

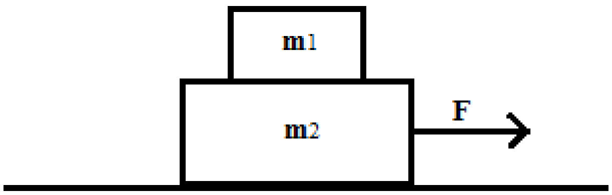
$$\sum \vec{F} = m\vec{a}. \qquad (1)$$

In this equation $\sum \vec{F}$ is the (vector) sum of all the forces acting *directly* on the *system*, m is the mass of the *system* and $\vec{a}$ is its (vector) acceleration.

Now we explain the concept of the system which we believe is really important in dynamics. System is a body which we separate from environment and then we study all the forces only acting directly on the system using Newton's second law. Emphasis on this concept necessitates analysis of every single body of the system so that forces like static friction become much more noticeable and outstanding. In fact we show that studying all the bodies in dynamics problems is really necessary. Most mechanics books avoid to analyze single bodies of the set in solving dynamics problems including two or more objects with the same behavior (*i.e.* acceleration) and only use one equation (Newton's second law) for the whole set of bodies at first. Although this method leads us to the right answer. But we think it doesn't have a clear physical meaning to solve these problems this way and its meaningless to use one equation at first.

Example 1

In the following figure, the blocks of masses m_1 and m_2 are to be considered. F is external force, and acting on the m_2 so that m_1 is at rest on the m_2. The friction between m_2 and the horizontal surface is ignored [2].



For the solution of this problem at first we consider m_1 as a system. Since m_1 is always at rest then we consider static friction between m_1 and m_2, so

$$f_s = m_1 a. \tag{2}$$

Now we consider m_2 as a system then

$$F - f_s = m_2 a. \tag{3}$$

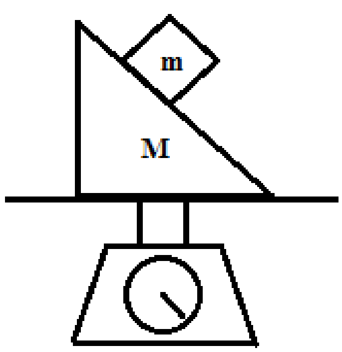
By the combination of Eq. (2) and (3) we have

$$F = (m_1 + m_2) a. \tag{4}$$

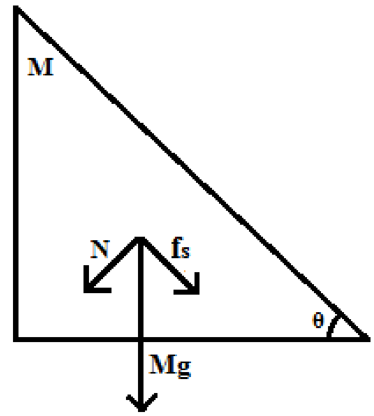
As you know classic mechanics books write Eq. (4) for problems such as Example 1 which is physically meaningless because force is only acting directly on m_2 therefore Eq. (4) is only acceptable as a result of combining Eqs. (2) and (3), and we think it's improper to use Eq. (4) at the beginning for such problems.

Example 2

In the figure, the block of mass m is at the rest on the inclined plane of mass M and the set of block are at the rest on the scale. We want to determine what scale shows (the angel of the inclined plane is θ).



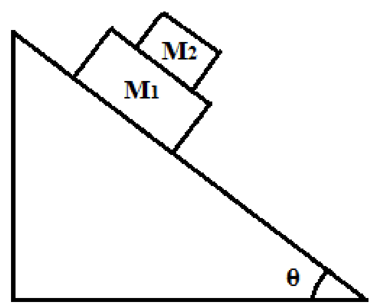
We consider the inclined plane as a system then the scale shows



$$Mg + \sqrt{N^2 + f_s{}^2} = Mg + mg. \tag{5}$$

Example 3

Consider two blocks of mass M_1 and M_2 so that both of them slide on the inclined plane with the angel of θin which the coefficient of friction between the M_1 and surface of inclined plane is μ. M_2 is at rest on the M_1 and inclined plane is at rest on the horizontal surface. Calculate acceleration of each of the blocks.



At first we consider M_2 as a system then we have

$$f_s = M_2 a - M_2 g \sin\theta. \tag{6}$$

Then we consider M_1 as a system so

$$M_1 g \sin\theta - (f_s + f_k) = M_1 a. \tag{7}$$

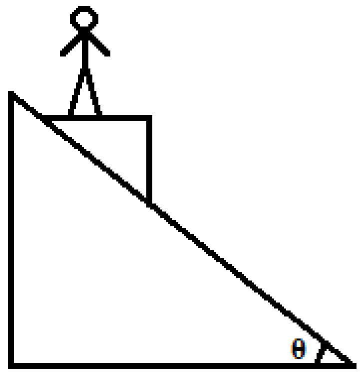
By the substitution of Eq. (6) and $f_k = \mu_k N$ we obtain

$$a = g \sin\theta - \mu_k g \cos\theta. \tag{8}$$

Example 4

A person stands on a platform which is sliding on an inclined plane and the inclined plane makes the angel $\theta$with the horizontal surface. While this platform slides down, the ratio between the vertical force that the platform inserts to the person and the weight of person is K(K<1).

What is the coefficient of friction between the platform and the inclined plane?



For the solution of this problem we consider the person as a system. And the mass of the person is m. Then we have

$$mg\sin\theta + f_s\cos\theta - N\sin\theta = ma. \tag{9}$$

In which according to the Eq. of (8)

$$a = g\sin\theta - \mu_k g\cos\theta.$$

And

$$f_s = ma\cos\theta, N = K(mg).$$

So

$$\mu_k = \frac{k\tan\theta - \frac{1}{2}\sin 2\theta}{sin^2\theta}. \tag{10}$$

III. CONCLUSION

The suggested concept in this paper can offer a new and deeper confrontation with dynamical problems; more ever it produces a new interpretation of Newton's second law. We suggest trying to find more examples in which the contribution of static friction is noticeable after reading this paper.

REFERENCE

[2] Shahen Hacyan,*what does it mean to modify or test Newton's second law*?,Am.J.Phys.77(7),(2009).
[1] Resnik, R., Halliday, D. & Krane, K. S., *Physics (volume 1),* 4th Ed. (Wiley, New York, 1992).