

Newton's Second Law

Objectives

1. To verify experimentally the relationship between the force acting on an object, its mass, and acceleration.

Introduction

According to Newton's second law, the acceleration, a , of a body is directly proportional to the net force acting on the body, $\Sigma \vec{F}$, applied to the body:

$$\Sigma \vec{F} \propto m\vec{a} \quad (1)$$

where m is the mass of the body.

The experimental setup for this experiment is shown in Figure 1 and is described below with notation.

A force $\vec{F}$ (tension) will be applied to directly m_{cart} . The measured acceleration will be a_{cart} . A spring with constant k is attached to m_{cart} . It is connected to the known masses hanging on the left through the pulley. Let us denote the unknown constant as:

$$\Sigma \vec{F}_{\text{spring}} \propto m_{\text{spring}} \times \vec{F} \quad (2)$$

Then, if the mass of the cart, m_{cart} , is doubled while $\vec{F}$ is kept constant, the acceleration of the cart, a_{cart} , is halved. Correspondingly, if $\vec{F}$ is doubled while m_{cart} is held constant, the acceleration of the cart is doubled. This analysis assumes a frictionless pulley.

To achieve the simplicity of the force of a better spring on the cart, the known mass, M , will be connected to the cart with a spring. A springless one-mass system (where the weight of M is equal to the known M force acting on $\vec{F}$) is equivalent with the simplicity of:

$$\Sigma \vec{F}_{\text{spring}} \propto m_{\text{spring}} \times \vec{F} \text{ and } m_{\text{cart}} \propto M \text{ and } \vec{F}$$

In equilibrium, the cart will be in motion without having any external velocity. A force $\vec{F}$, m_{cart} , and the known mass M through a spring, m_{spring} , is attached to $\vec{F}$ with no change.

Given $\vec{F}$ (the force) is constant, any additional mass will be directly related to the acceleration of the system. In a Fig. 1 (b), the added mass, m_{spring} , creates a direct equal force through the cart, tension system.

At equilibrium, the cart is at rest.

$$m_{\text{cart}} = \frac{m_{\text{spring}}}{m_{\text{spring}}}$$

(3)

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**National Science Foundation (U.S.).
Office of Experimental Projects and
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