

# Verification of the Newton's 2nd Law of Motion

Tuesday, 1st March, 2022

**PH1102: Physics Lab I**

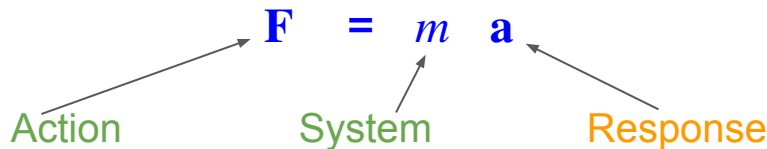
# Newton's Second Law

The force  $\mathbf{F}$  required to move a body of given mass with an acceleration  $\mathbf{a}$  is proportional to the acceleration  $\mathbf{a} \Rightarrow \mathbf{F} \propto \mathbf{a}$

The force  $\mathbf{F}$  required to move a body of mass  $m$  with a given acceleration  $\mathbf{a}$  is proportional to the mass  $m \Rightarrow \mathbf{F} \propto m$

$$\mathbf{F} \propto m \mathbf{a} \quad \Rightarrow \quad \mathbf{F} = K m \mathbf{a}$$

*We choose the unit and dimension for force such that  $K$  is unit and dimensionless.*



# The System $m$

The body to be moved under the influence of the applied force is called system here and it is described by its mass  $m$ .

**Lab:** In the laboratory experiments it is tuned by loading the *slider* with different weights

# The Action **F**

We generate and control the acting force **F** by means of the second law of motion itself.

We use some weight and hang it from a string. The generated force is proportional to the constant acceleration due to gravity and the mass of the hanging weight.

We control the generated force by changing the hanging weight.

# The Response $a$

The response  $a$  is to be measured. And all the experimental setup and post processing of the data is designed to estimate the acceleration  $a$  of the body under a chosen set of experimental conditions.

This is done by measuring position as a function of time.

**Lab:** In laboratory, the position is measured at regular interval by a camera

# Experimental Setup and Data analysis

**Setup:** The hanging weight is connected (by a string) to a movable setup (cart or slider) on an almost frictionless horizontal surface

## Laboratory

For the laboratory experiment, the experimental setup, execution, data collection and the analysis will be demonstrated in a prerecorded video.

## Simulation

For the online experiment, the experimental setup, execution, data collection and the analysis will be demonstrated live during the class.

# Working Formula

Let  $T$  be the tension in the string connecting slider and the hanging weights:

For the (vertical) motion of the hanging weight  $m$   $T = mg - ma$

For the (horizontal) motion of the system  $M$   $T = Ma + \mu Mg$

Here  $g$  is acceleration due to gravity and  $\mu$  is coefficient of friction.

$$a = (mg - \mu Mg)/(m+M) = g (m - \mu M)/(m+M)$$

For  $\mu=0$ , we have  $a = mg/(m+M)$ , i.e  $a \propto F$  and  $a \propto 1/(m+M)$

In the experiment, we try to minimize the friction by using air track and use  $(m+M)$  as the mass of the system that moves.

# Laboratory Demonstration Video

Dr. Rumi De



# Data Processing : Fixed mass case

1. Look at the x vs t data for fixed mass case. Plot x vs t plot.
2. Using mid-point derivative, compute v vs t and plot.
3. Using finite difference formula, compute a vs t and plot.
4. Using fitting to  $c + v \cdot t + a \cdot t^2/2$  obtain acceleration a for each case.
5. Plot Force (=mg) vs fitted acceleration and obtain a linear fit.

$$v(t+dt/2) = [x(t+dt) - x(t)]/dt$$

$$a(t) = [x(t+dt) + x(t-dt) - 2 x(t)]/dt^2$$

# Data Processing : Fixed force case

1. Look at the  $x$  vs  $t$  data for fixed force case. Plot  $x$  vs  $t$  plot.
2. Using mid-point derivative, compute  $v$  vs  $t$  and plot.
3. Using finite difference formula, compute  $a$  vs  $t$  and plot.
4. Using fitting to  $c + v*t + a*t^2/2$  obtain acceleration  $a$  for each case.
5. Plot total mass vs fitted inverse acceleration and obtain a linear fit.

$$v(t+dt/2) = [x(t+dt) - x(t)]/dt$$

$$a(t) = [x(t+dt) + x(t-dt) - 2 x(t)]/dt^2$$

# Analysis and Plots

1. Plot force vs acceleration in the fixed mass case.
2. Plot mass vs inverse acceleration in the fixed force case.