Historical Overview

Isaac Newton (1643 - 1727)

- Built on the results of Galileo and Kepler
- Added physics interpretations to the mathematical descriptions of astronomy by Copernicus, Galileo and Kepler

Major Achievements:
1. Invented calculus as a necessary tool to solve mathematical problems related to motion
2. Discovered the three laws of motion
3. Discovered the universal law of mutual gravitation

Newton’s Laws of Motion

- Law of Inertia:
  - an object in motion stays in motion, and an object at rest stays at rest, unless acted on by a force
  - Also can be expressed as conservation of linear momentum

\[
\frac{dp}{dt} = 0 \text{(no force)}
\]

where vector notation implies

\[
\begin{bmatrix}
\frac{dp_x}{dt} \\
\frac{dp_y}{dt} \\
\frac{dp_z}{dt}
\end{bmatrix} = 0
\]
Newton's Laws of Motion

• **Newton’s 2nd Law:** \( F = m \ a \)

\[
\begin{bmatrix}
F_x \\
F_y \\
F_z
\end{bmatrix} =\begin{bmatrix}
dp_x/dt \\
dp_y/dt \\
dp_z/dt
\end{bmatrix} = \begin{bmatrix}
dv_x/dt \\
v_y/dt \\
v_z/dt
\end{bmatrix} = \begin{bmatrix}
a_x \\
a_y \\
a_z
\end{bmatrix}
\]

Newton’s Laws of Motion

• **Newton’s 3rd Law:** action-reaction pairs
  • In a closed system, the force exerted on \( m_1 \) by \( m_2 \) is equal and opposite to the force exerted on \( m_2 \) by \( m_1 \).
  • **Conservation of momentum** requires this.

The Universal Law of Gravity

• Any two bodies are attracting each other through gravitation, with a force proportional to the product of their masses and inversely proportional to the square of their distance:

\[
F = -G \frac{Mm}{r^2}
\]

(G is the gravitational constant.)
Weight and Gravitational Acceleration

- Derive formula for the acceleration of gravity, \( g \).

Orbital Motion

In order to stay on a closed orbit, an object has to be within a certain range of velocities:

Too slow: Object falls back down to Earth

Too fast: Object escapes the Earth's gravity

Group work

- Derive Kepler's 3rd Law from Newton's law of gravity and centripetal acceleration (\( v^2/r \)).
MATLAB Exercise

- Complete the introduction to MATLAB
- Complete Ch 1: Problem 4 using MATLAB.
- Bonus: complete Problem 1.3(b) using MATLAB.