4 – Newton’s laws

Aristotle (384-322 b.c.)
12 century -> Latin Dominating views

„Forces cause objects to move;
No force – no velocity“

Aristotle disregarded friction forces

Galilei (+2000 years)
Questioned Aristotles

„Forces cause objects to accelerate;
No force – velocity constant“

\[ v = v_0 + at \]
\[ x = x_0 + v_0 t + \frac{1}{2} at^2 \]

Newton (1642-1727)
1687 – The mathematical Principles of Natural Philosophy (Principia)

Newton’s laws: Foundation of modern Physics

Newton mechanics

- Relativistic mechanics
  \[ v \sim c = 3 \cdot 10^8 \text{ m/s} \]

- Quantum Mechanics
  \[ m \sim m_e \sim 10^{-30} \text{ kg} \]
Newton’s first law:
Objects that are not subject to action of forces are moving with zero or constant velocity
(follows from the second law; has historical significance – disproves Aristotle)

Newton’s second law: \( F = ma \)

\( F \) – force; \( m \) – mass; \( a \) – acceleration

Unit of force: kg m/s\(^2\) = N(ewton)

Allows to compute acceleration from force etc.

Consequences: (i) First law for \( F = 0 \);
(ii) Statics for \( a = 0 \), i.e., \( F = 0 \) (important applications in engineering)

Force \( F \) is the sum of all forces acting on the object:

\[
\sum_{i} F_i = F_1 + F_2 + F_3 + \ldots
\]

Addition of vectors

Mass \( m \) is the measure of inertia of the object
Newton’s third law: \( F_{12} = -F_{21} \)

Helps to identify forces in systems of interacting bodies

Example: Measuring weight with a spring scale

Two objects pressed against each other

\[
\begin{array}{c}
1 \\
\hline
F_{12} \\
\hline
F_{21} \\
2
\end{array}
\]

Two objects connected by flexible thread

\[
\begin{array}{c}
1 \\
\hline
F_{12} \\
\hline
F_{21} \\
2
\end{array}
\]

In isolated systems the sum of all (internal) forces is zero;

Only external forces can accelerate the system as the whole

Examples:
- rocket
- car,
- smart mule
- Baron Münchhausen

In this way the weight \( W = mg \) is measured

\[
mg + F_{12} = 0
\]

\[
F_{12} = -mg
\]
### Friction

- Sliding friction -> static friction
- Rolling friction
- Viscous friction

#### Sliding friction

\[
F_{fr} = \begin{cases} 
\mu F_N, & v \neq 0 \\
\mu_s F_N, & v = 0 
\end{cases}
\]

\[\mu_s > \mu\]

Surfaces are rough.
Rolling friction

Viscous friction

Air or liquid

\[ F_{fr} = -\alpha v \]
Inclines

For a moving block

\[
F_N + (mg)_y = F_N - mg \cos \theta = 0
\]

\[
F_{fr,x} + (mg)_x = -\mu F_N + mg \sin \theta = ma
\]
Problems:

♦ Two blocks joined by thread

\[ m_1 \text{ F}_{12} \quad \text{F}_{21} \quad m_2 \]

\[ F_{12} \text{ - ? (tension of the thread)} \]

a - ?

♦ Apparent weight in elevator

N - ?

\[ m \text{g} \]
1. If \( a=0 \), \( F - ? \) (Statics)
2. If \( F \) given, \( a - ? \)

♦ Pulley
Pulling a boat

Known: $F$, $\alpha$

Find: pushing force $f$, net force