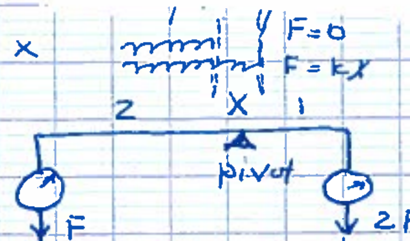
— Force : ↔ interaction

* units of force – N (newton) $= 1\,kg\,m/s^2$
* How to measure : spring
  Hook's law : $F = kx$



Force field (vector field)
spring balance
by adjusting the pivot
we can calibrate it.

— Mass – measure of the object's inertia –
– its resistance to being accelerated.

What is the origin of mass? CM is not concerned with this philosophical question.

* inertial balance – a way how we can compare masses
* Units of mass : just pick some reference mass and call it a kilogram. All other masses are measured in units of the ref. mass.
* mass vs weight – what is the difference?
  "inertia" ↔ "force" due to Earth gravity.
* Inertial mass vs gravitational mass
  1) no measurable difference
  2) IM ≡ GM – the equivalence principle.

— Newton's First & Second Laws

* the law of inertia (see the book)
* $\vec{F} = m\vec{a}$ $\quad \vec{a} = \vec{F}/m$ $\quad \vec{F}$ is the sum of all forces acting on the particle.

$m\ddot{\vec{r}} = \vec{F}$
diff. equation
(Chapter 1.4)

$\vec{F} = m\vec{a} = m\dot{\vec{V}} = \dot{\vec{p}}$ – rate of change of the particle momentum

momentum: $p = mv$

* Reference frames (chapter 1.4)
  the role of the first law → distinguish between "inertial" and "non-inertial" frames

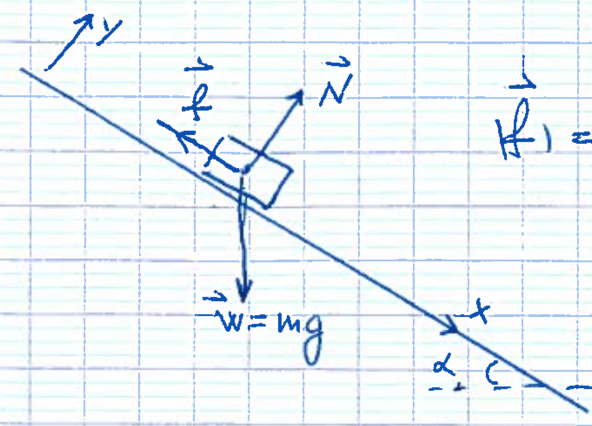
Validity of N1 & N2 Laws
(chapter 1.4)

FIGURE 1.4 from the book.

The laws of nature do not depend on selection of the ref. frame, but our formulation of laws of nature do

L3

Example 1.1 a block sliding down an incl
(for details see the textbook)



$|\vec{f}| = \mu|\vec{N}|$

a) $\dot{y} = 0 \rightarrow F_y = 0 = N - mg\cos\alpha = 0$

$N = mg\cos\alpha$

b) $f = \mu N = \mu mg\cos\alpha$

c) $F_x = mg\sin\alpha - f = mg(\sin\alpha - \mu\cos\alpha) = m\ddot{x}$

$\ddot{x} = g(\sin\alpha - \mu\cos\alpha)$ - diff. eq. for

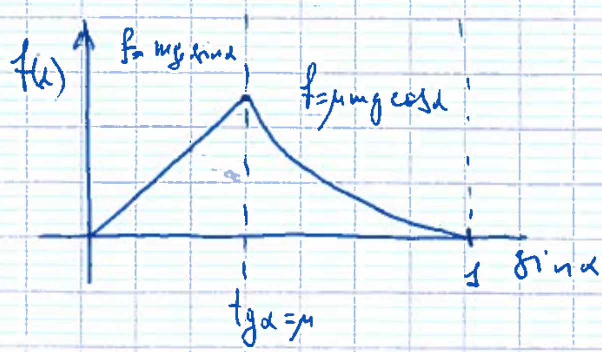
$\ddot{x}$ = const.!

$\dot{x} = g(\sin\alpha - \mu\cos\alpha)t + V_0$; $V_0 = 0$ at $t=0$

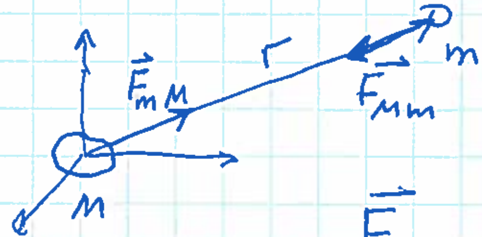
$x = \frac{1}{2}gt^2(\sin\alpha - \mu\cos\alpha) + x_0$; $x_0 = 0$ at $t=0$

Caveat: What if $\sin\alpha - \mu\cos\alpha < 0$?

$f(\alpha) \leq \mu N$



* Newton's law of gravitation



$$\vec{F}_{Mm} = -\frac{GMm}{r^2}\hat{r}$$ – force from M to m

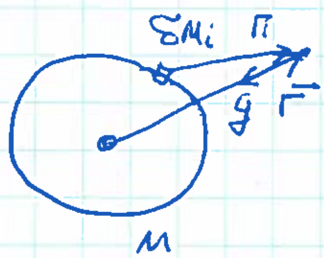
$$\vec{F}_{mM} = \frac{GMm}{r^2}\hat{r}$$ – force from m to M

* gravitational field (acceleration)

$$\vec{g}_M = \vec{F}_{Mm}/m = -\frac{GM}{r^2}\hat{r}$$

$$\vec{g}_m = \vec{F}_{mM}/M = \frac{Gm}{r^2}\hat{r}$$

* gravitational field of a sphere of mass M



$$\delta g_i = -\frac{G\delta M_i}{r_i^2}\hat{r}_i$$

$$\vec{g} = -\sum_i \frac{G\delta M_i}{r_i^2}\hat{r}_i = -\frac{GM}{r^2}\hat{r}$$

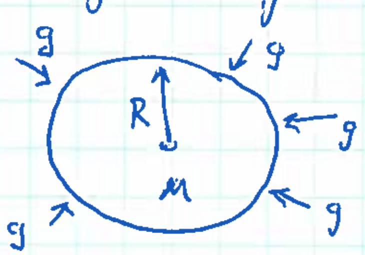
* Gauss flax theorem for gravity

$$\oint \vec{g}\cdot d\vec{S} = -4\pi GM$$

↑ surface integral

$d\vec{S}$ – vector along the direction of the surface normal $\hat{n}$ $(d\vec{S} = |dS|\hat{n})$ with magnitude $|dS|$

* gravity of Earth (assuming solid uniform sphere)



$$\oint \vec{g}\, d\vec{S} = 4\pi R^2 g = -4\pi GM$$

$$g = -\frac{GM}{R^2}$$