ARK-A3001 Design of Structures_Basics
Equilibrium

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Equilibrium

lat. *aequus* = equal + *libra* = balance

What is it that we need to balance?

Baumschlager Eberle: Rohner Port Building
Fussach, Austria, 1999-2000

Equilibrium

Dead Load

- building materials
- installations

Live Load

- people
- furniture

Environmental Load

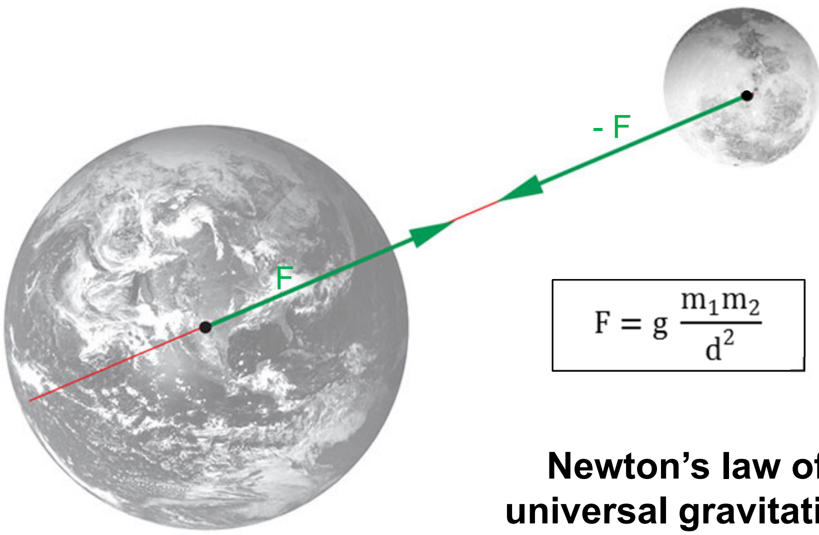
- snow
- wind
- earthquake
- soil pressure

The amount and location of loads is described by **forces**

Baumschlager Eberle: Rohner Port Building
Fussach, Austria, 1999-2000

Isaac Newton

every mass attracts every other mass in the universe with a force



$$F = g\,\frac{m_1 m_2}{d^2}$$

Newton's law of universal gravitation

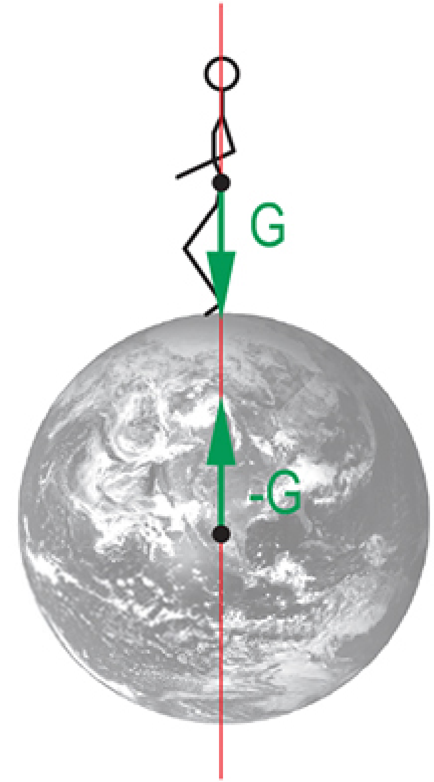
m_1,m_2 … masses
d … distance
g … gravitational constant

$$G = 9.81\ m$$

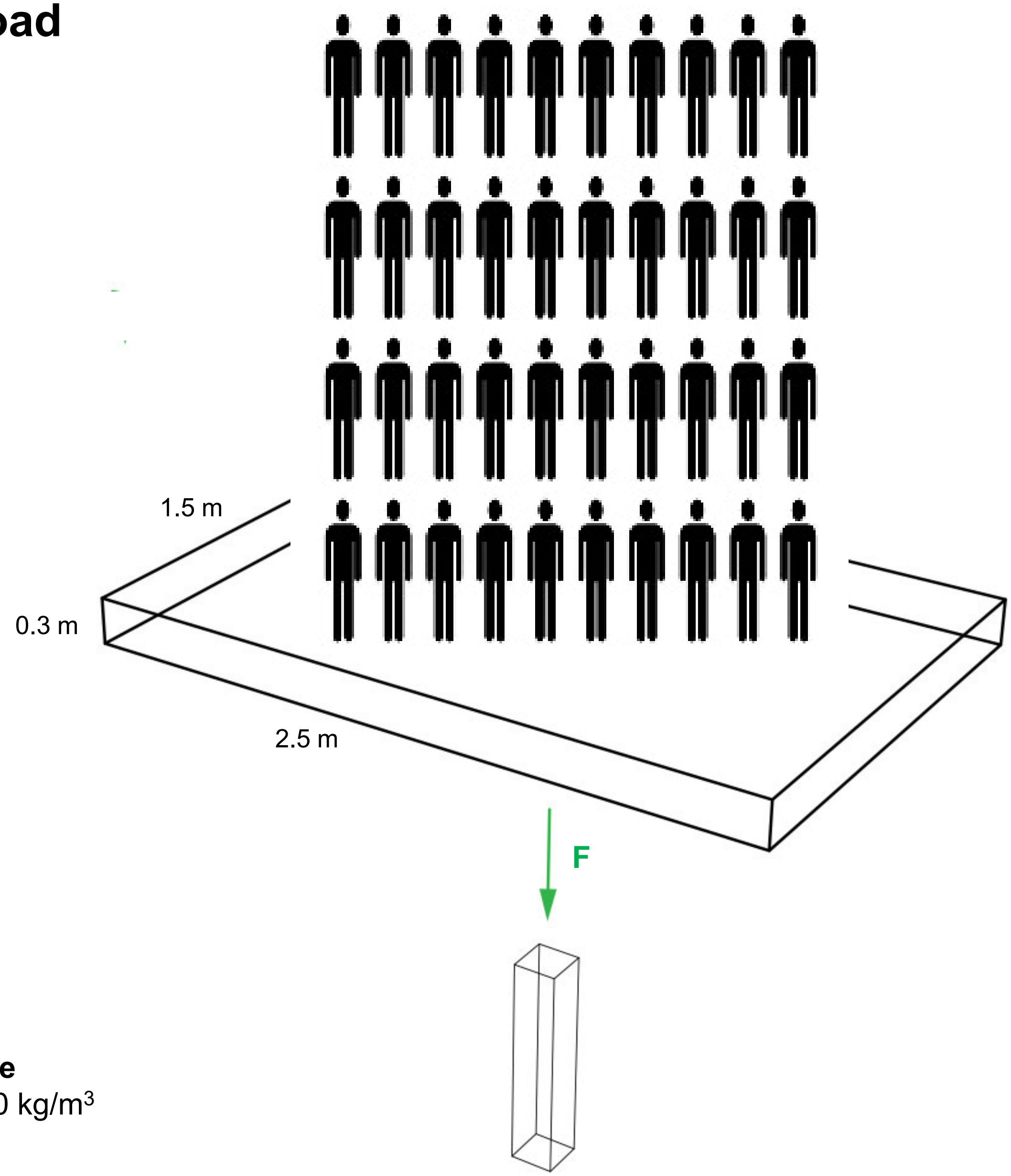
$$1\ [N] = 1\ [kg\ \frac{m}{s^2}]$$

gravitational load

m … mass



Gravitational Load

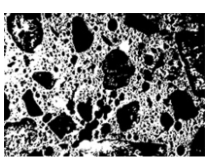


40 people
(around 75 kg / person)

$V = 1.125\ m^3$

$m = V \cdot \rho = 2'812.5\ kg$

$F = g \cdot m = 27'591\ N = 27.6\ kN$

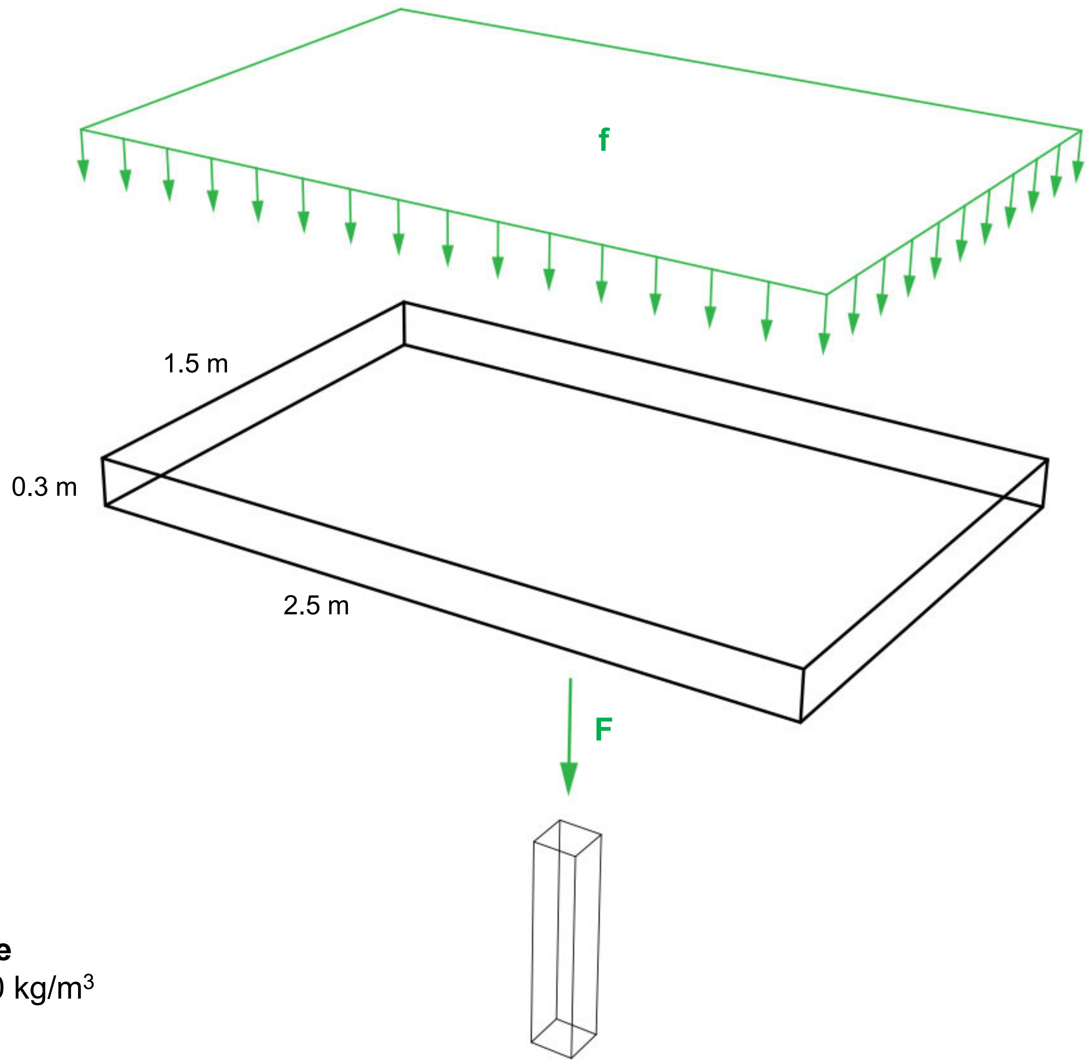


concrete
$\rho = 2500\ kg/m^3$

Gravitational Load

distributed load **f**

point load **F**



$A = 3.75\ m^2$

$f = F/A = 7.36\ kN/m^2$

$V = 1.125\ m^3$

$m = V \cdot \rho = 2'812.5\ kg$

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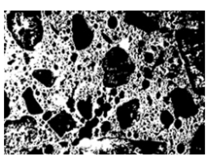


concrete
$\rho = 2500\ kg/m^3$

Equilibrium

Dead Load

building materials	distributed load
installations	point load / distributed load

Live Load

people	point load
furniture	point load / distributed load

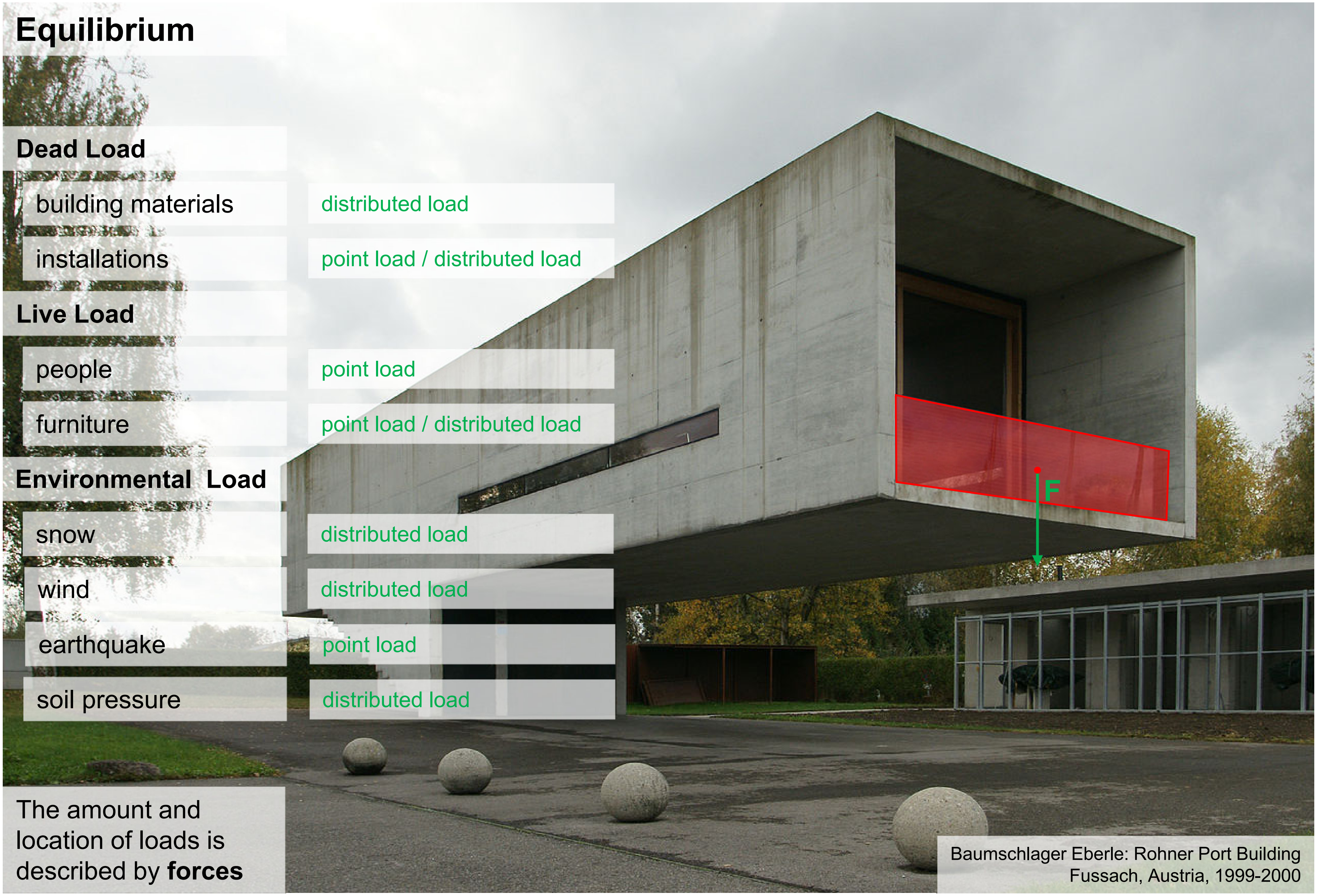
Environmental Load

snow	distributed load
wind	distributed load
earthquake	point load
soil pressure	distributed load

The amount and location of loads is described by **forces**

Baumschlager Eberle: Rohner Port Building
Fussach, Austria, 1999-2000

Equilibrium



Dead Load	
building materials	distributed load
installations	point load / distributed load
Live Load	
people	point load
furniture	point load / distributed load
Environmental Load	
snow	distributed load
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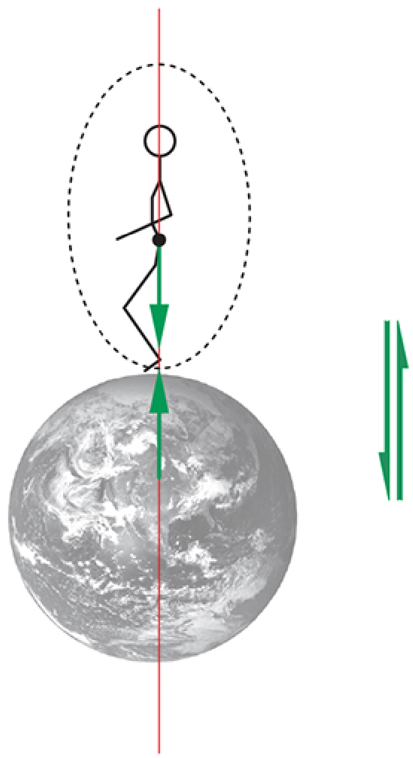
The amount and location of loads is described by **forces**

Baumschlager Eberle: Rohner Port Building
Fussach, Austria, 1999-2000

Isaac Newton
all forces between two objects
exist in equal magnitude and
opposite direction

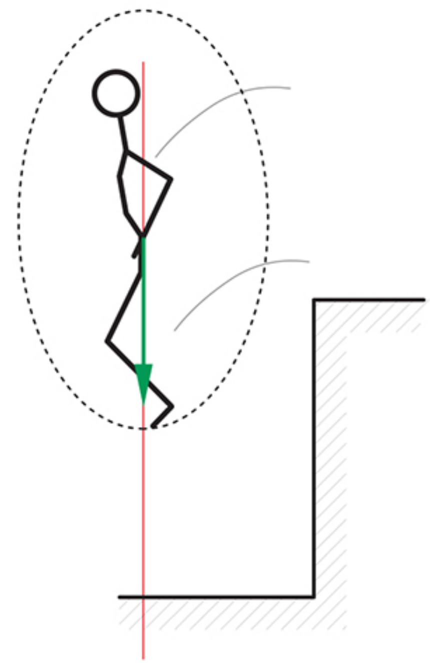
˝actio est reactio˝



equilibrium

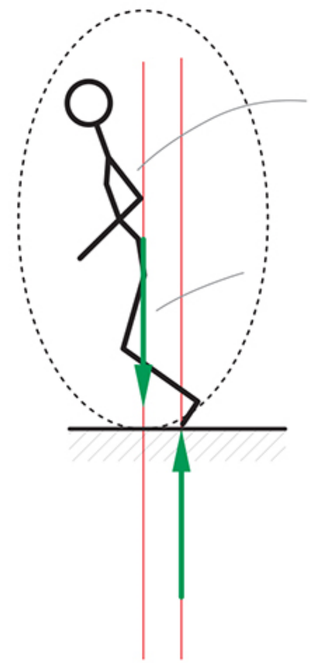
two potential sources of violation
of rule for equilibrium

not equal
magnitude



translation

not opposite
direction

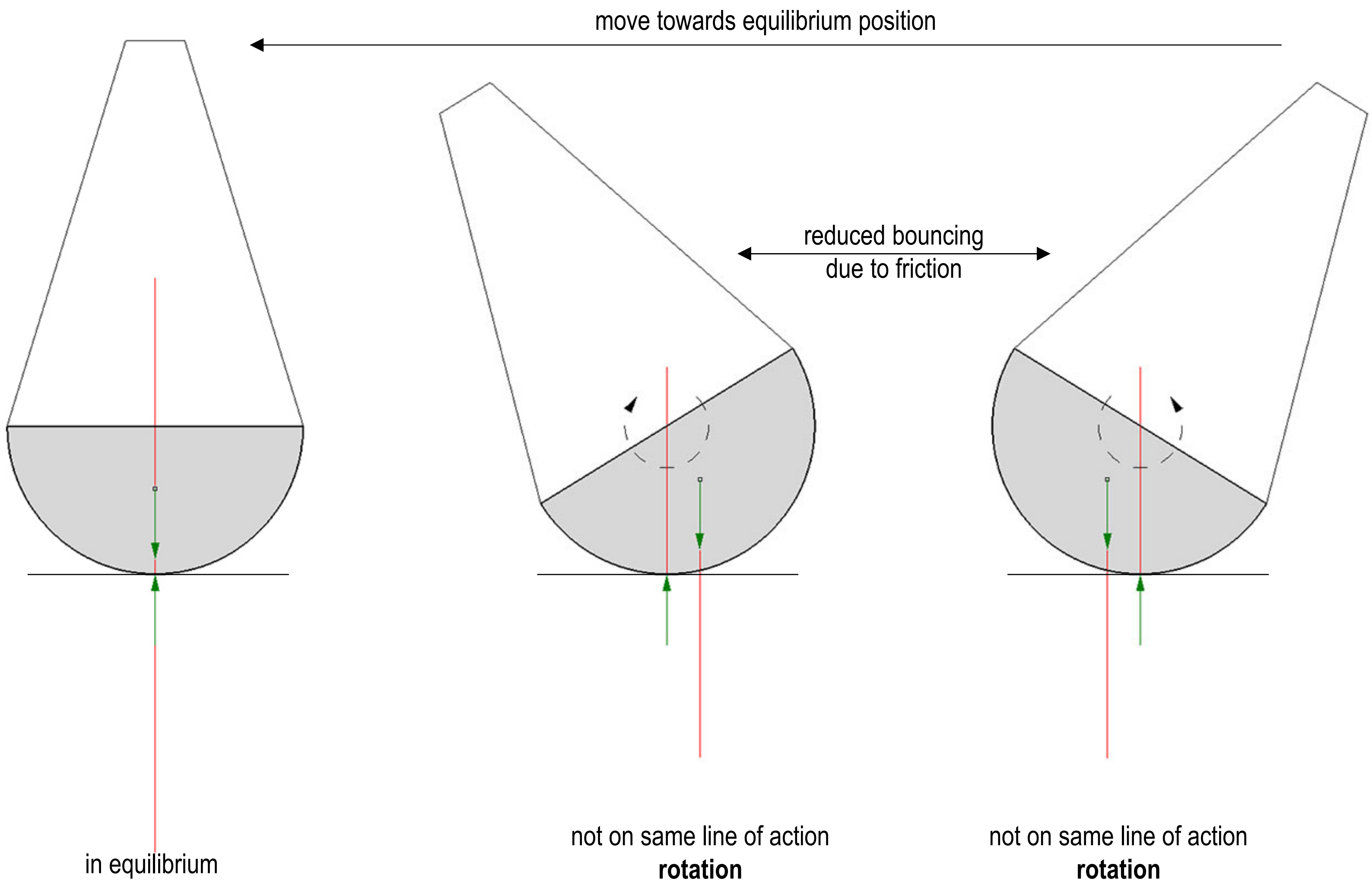


rotation

Equilibrium

Why is the figure always bouncing back?
Why does the figure always come to rest?

Equilibrium



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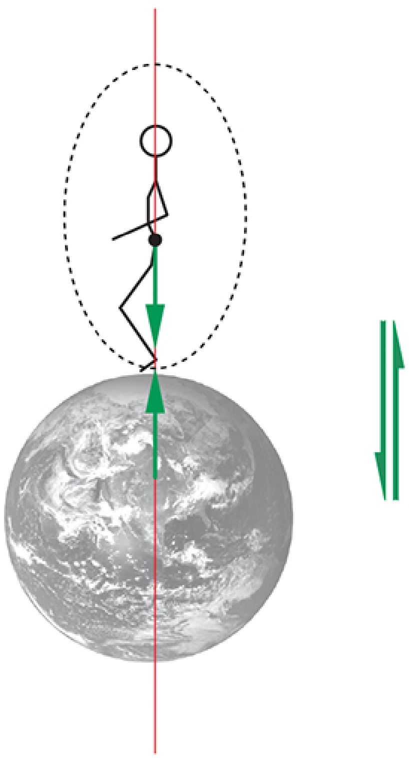
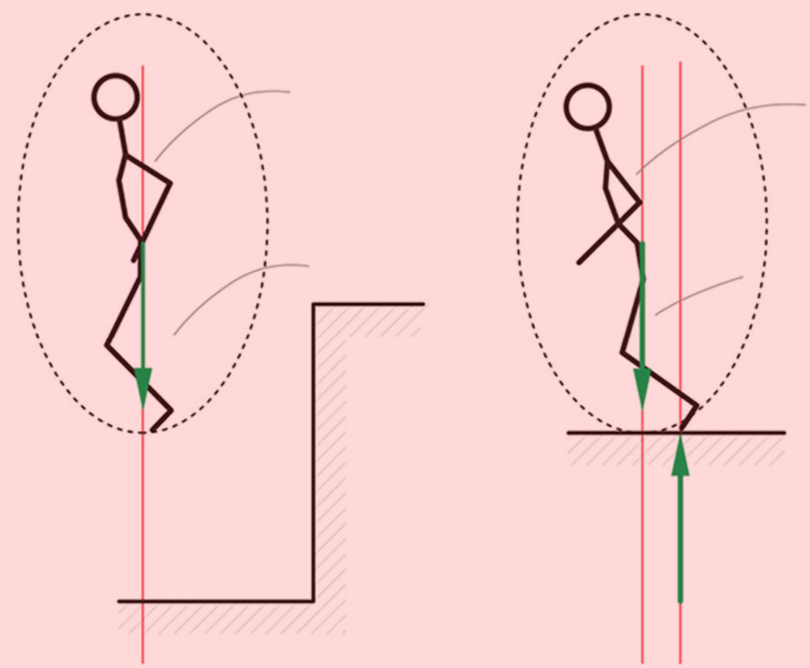


equilibrium

two potential sources of violation of rule for equilibrium

not equal magnitude

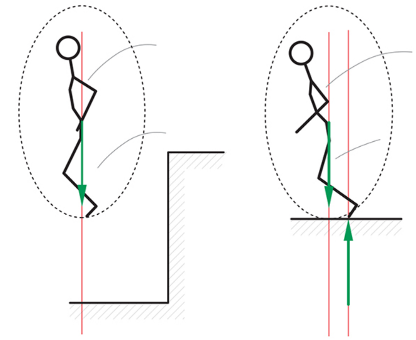
not opposite direction



translation

rotation

Equilibrium Condition

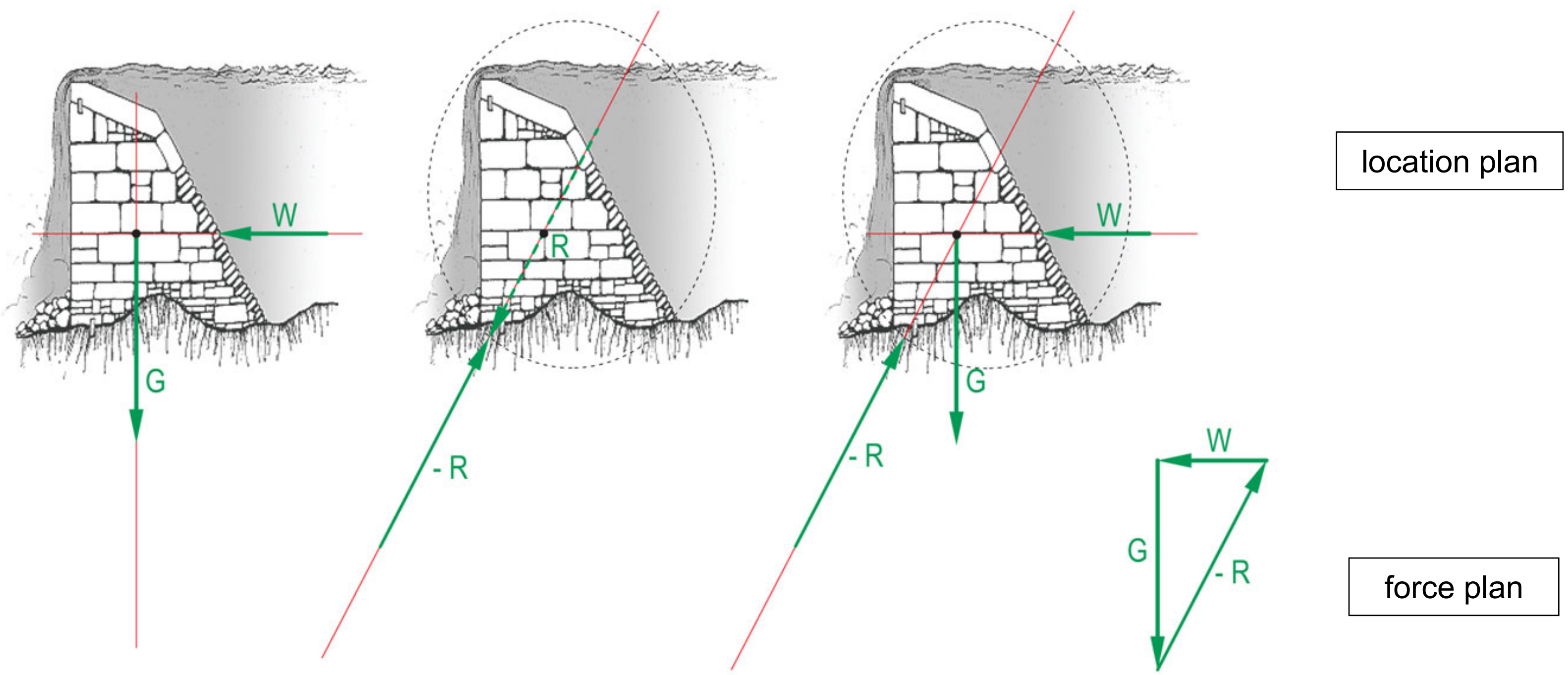


geometric description

the forces add up to zero
the line of action of the forces intersect in one point

both conditions are checked geometrically with

- location plan (line of action)
- force plan (forces add up)



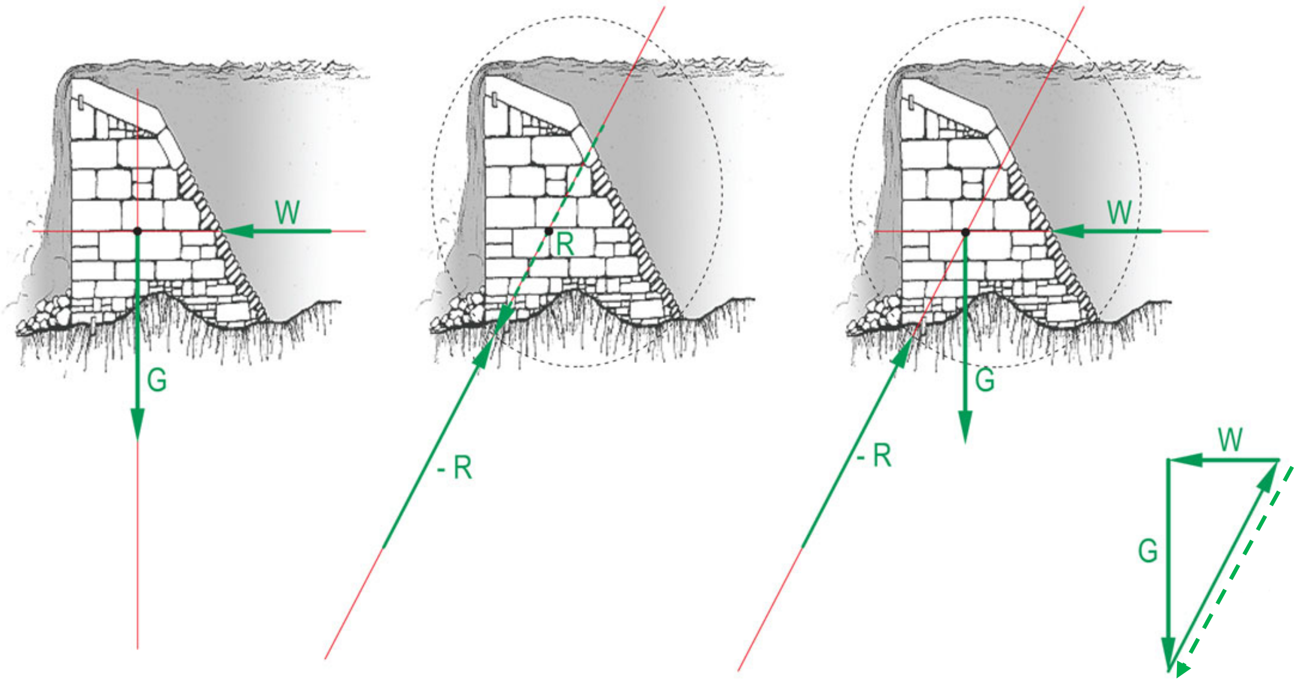
Aalto University Design of Structures
Toni Kotnik, Professor of Design of Structures

Resultant

R is the resultant of G & W

R has the same effect
as G & W together

R = G + W



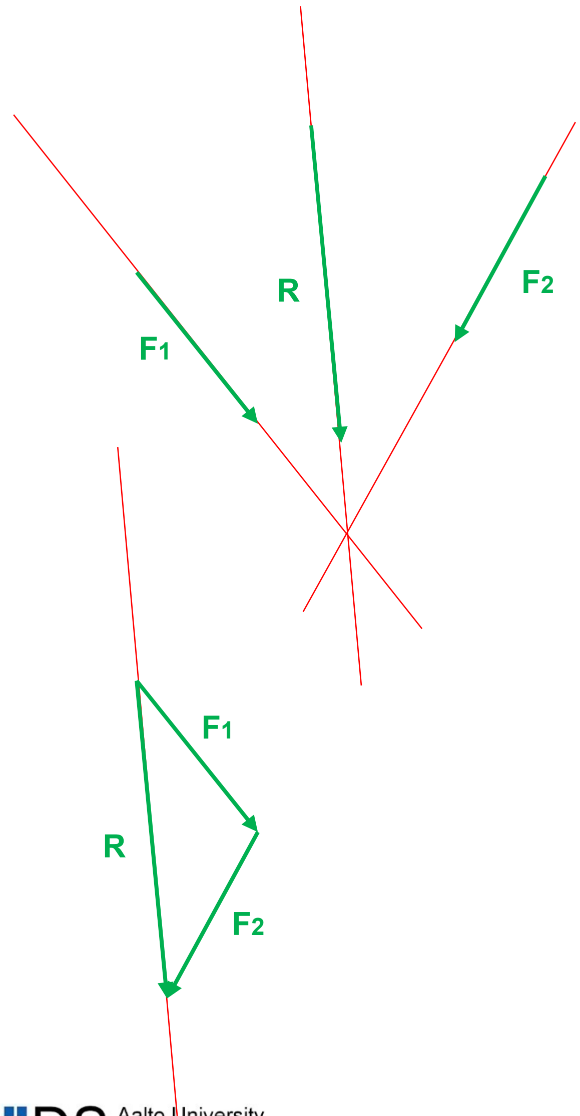
location plan

force plan

Basic Operation with Forces

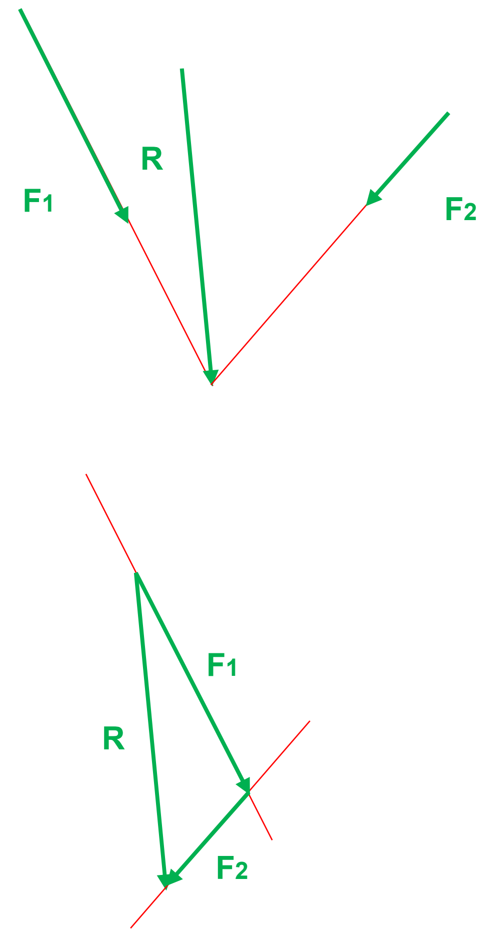
two forces can be added
into one resulting force

one force can be
separated into two force



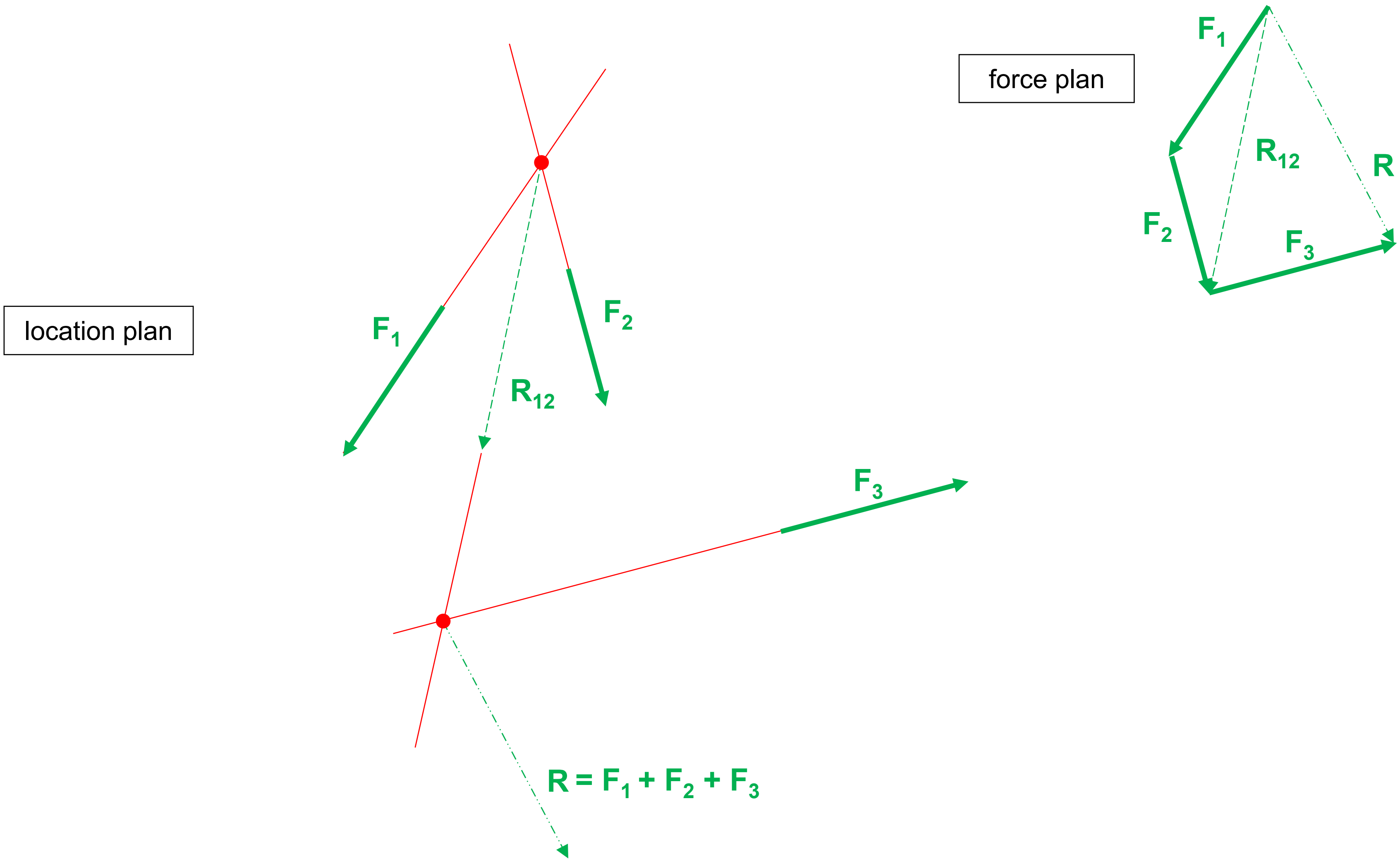
location plan

force plan



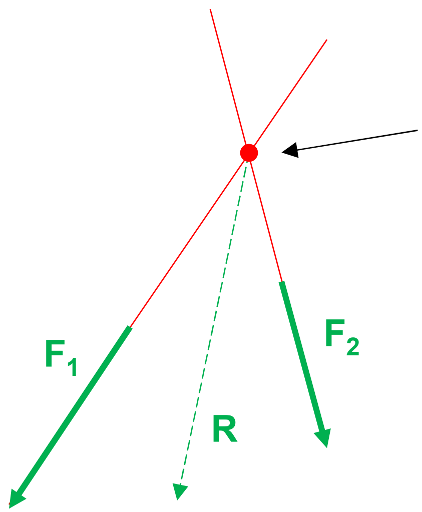
Basic Operation with Forces

construction of resultant



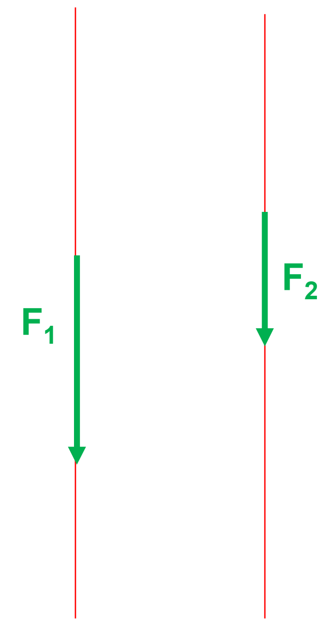
Basic Operation with Forces

construction of resultant



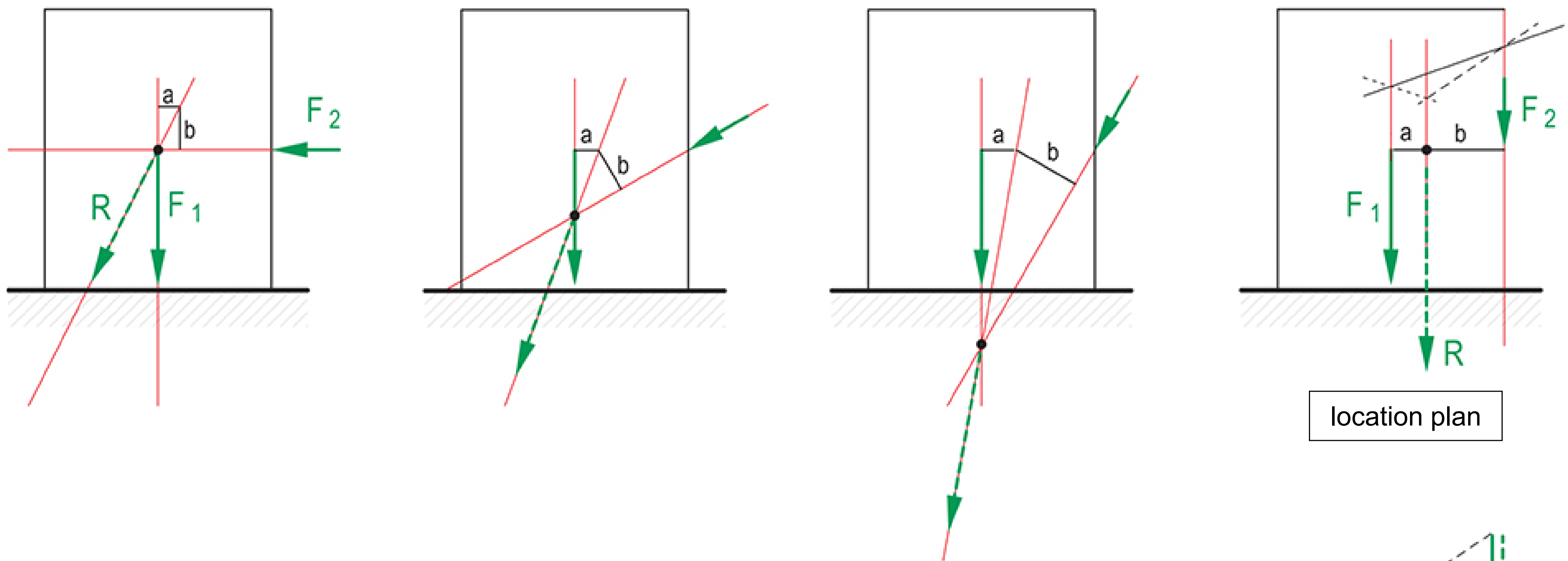
works well as long we have an intersection point

location plan

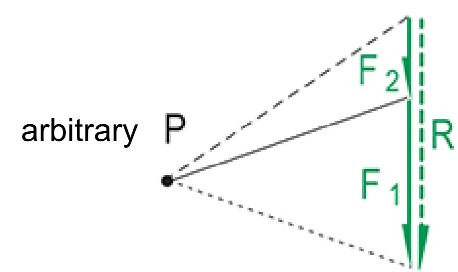


where is the resultant R located when the forces are parallel?

Lever Principle



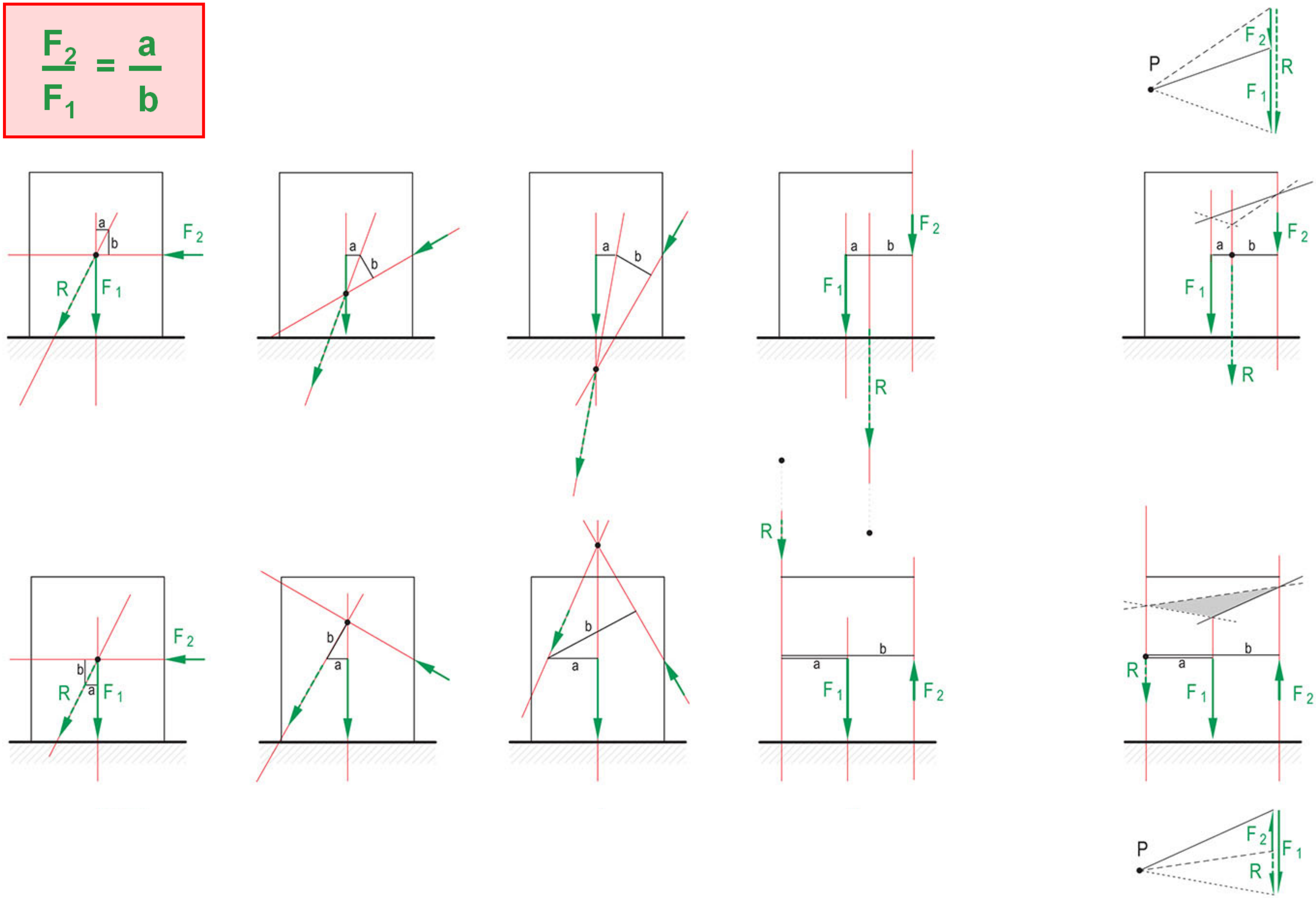
$$\frac{F_2}{F_1} = \frac{a}{b}$$



force plan

Lever Principle

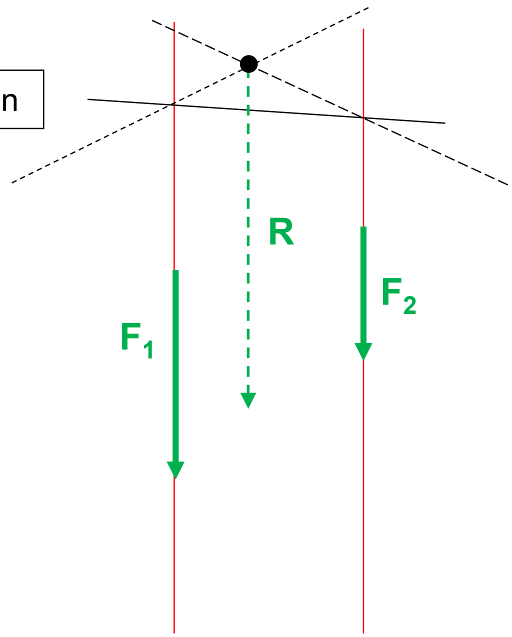
$$\frac{F_2}{F_1} = \frac{a}{b}$$

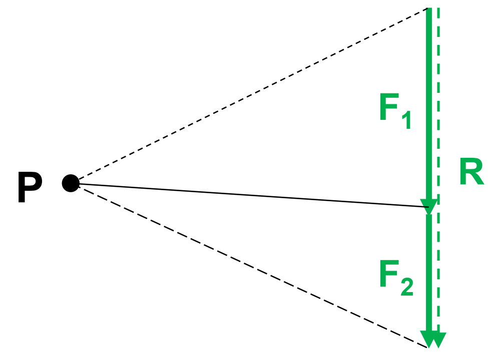


Lever Principle

geometric construction of resultant

location plan





force plan

Step 1: construct R in force plan

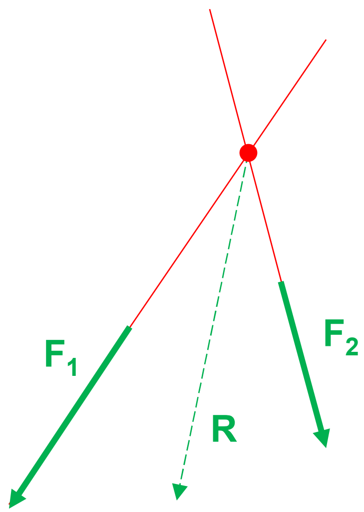
Step 2: pick P in force plan & construct rays

Step 3: move rays into location plan (parallel shift)

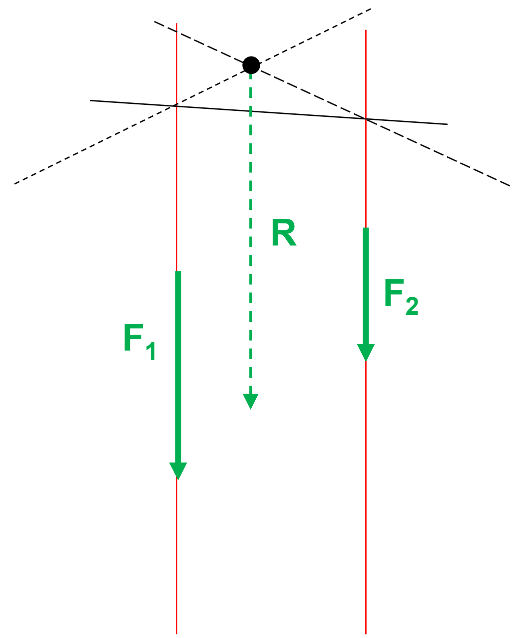
Step 4: locate R in location plan at intersection point

Basic Operation with Forces

construction of resultant



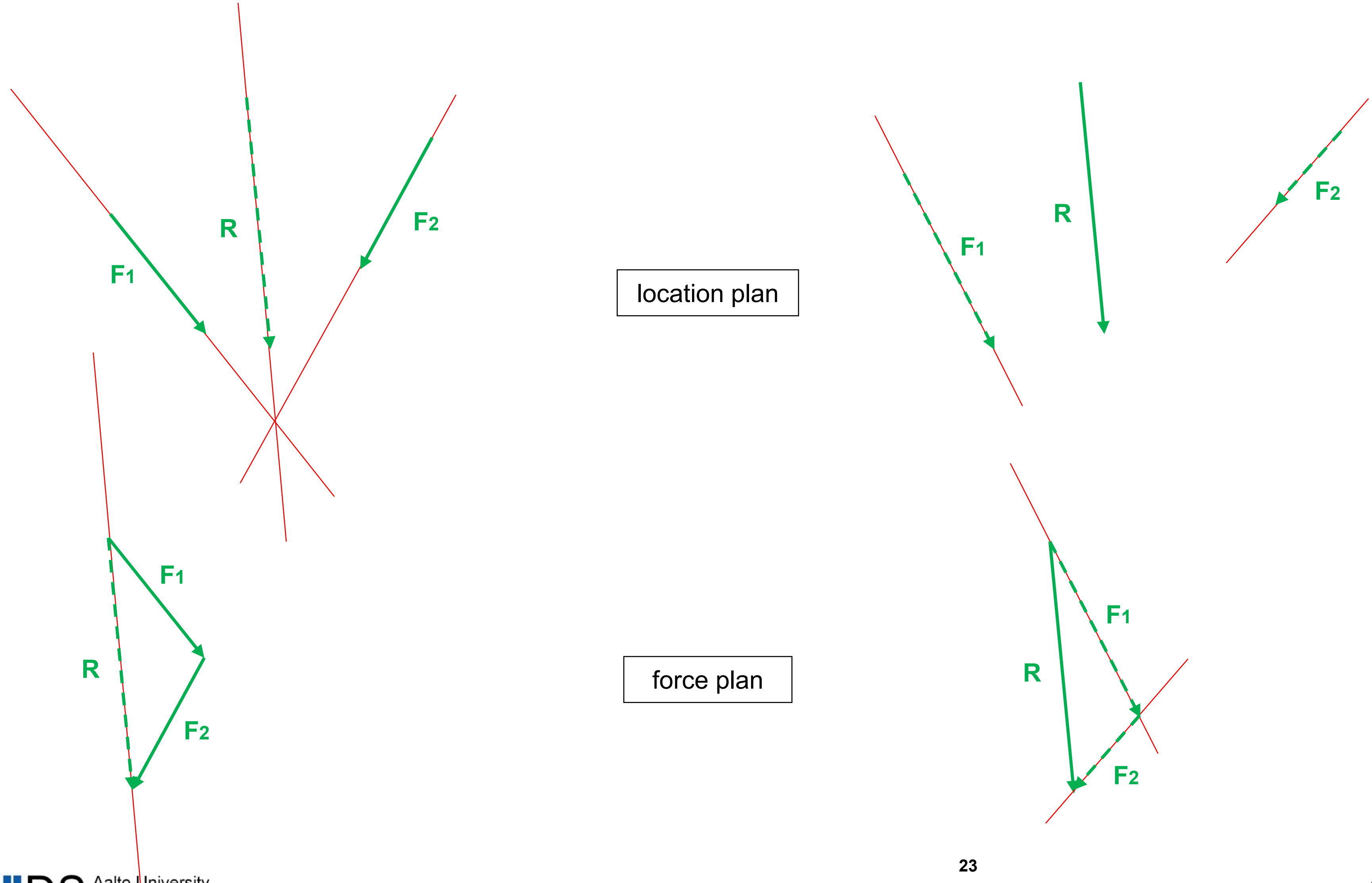
location plan



Basic Operation with Forces

two forces can be **added**
into one resulting force

one force can be
separated into two force



Load cases

- dead load
- live load
- environmental load

distributed load

point load

equilibrium

location plan

force plan

resultant force

lever principle

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Equilibrium

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Exercise 1.1

Construct the resultant of the four forces given in the location plan.

location plan

Exercise 1.2

Separate the force R into two parallel forces F_1 and F_2 in such a way that R is the resultant of these two forces and the magnitude of the forces F_1:F_2 = 3:1.

Exercise 1.3

The sculpture consists of three steel plates of size 160 x 160 x 7.6 cm (plate 1) respectively 160 x 213 x 5 cm (plate 2 & 3). The plates are stacked onto each other but neither screwed nor welded. Together they form a stable configuration in equilibrium. Why?

Richard Serra: Weights and Measure
Sculpture, Steel, Art Institute
Chicago, USA, 1987