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MINISTRY OF EDUCATION,
YOUTH AND SPORTS

Preparation of the international Ph.D. study programme "Environmental Engineering" CZ.02.2.69/0.0/0.0/16_018/0002660

Transport processes in rock and soil

Lecture 1

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Environmental Engineering

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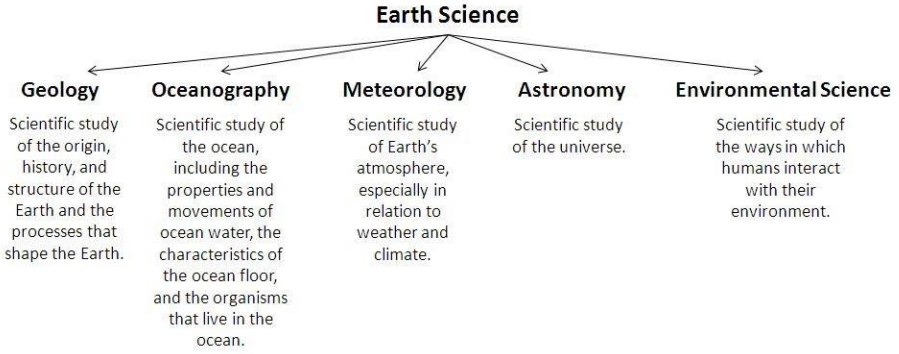
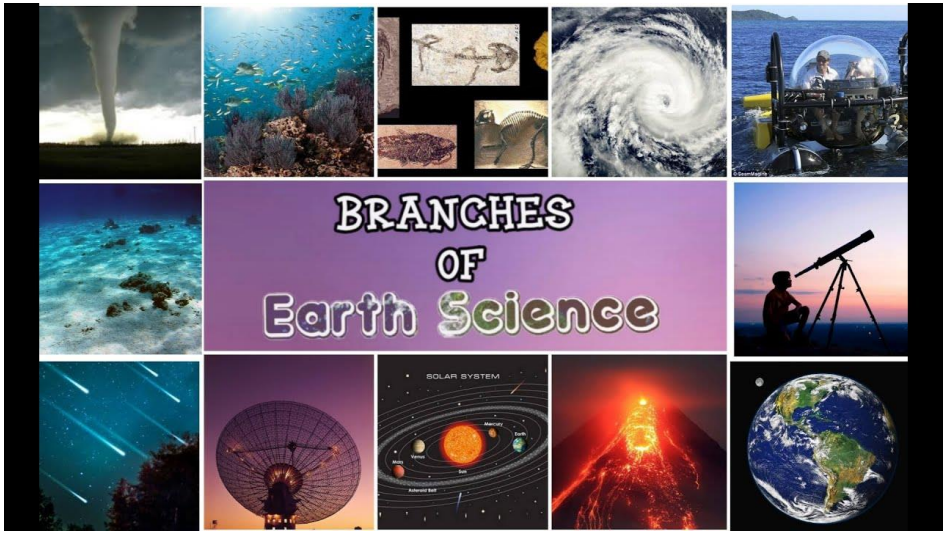
Organizing matters (PhD study)

- Lecture only (excercises optional)
- E-learning course
  - Literature (incl. electronic resources)
  - Example exam problems

- Exam
  - Oral with written preparation
  - According to PhD study rules

Geosciences / Earth sciences (CZ: vědy o zemi)





Branches of Earth science [edit]

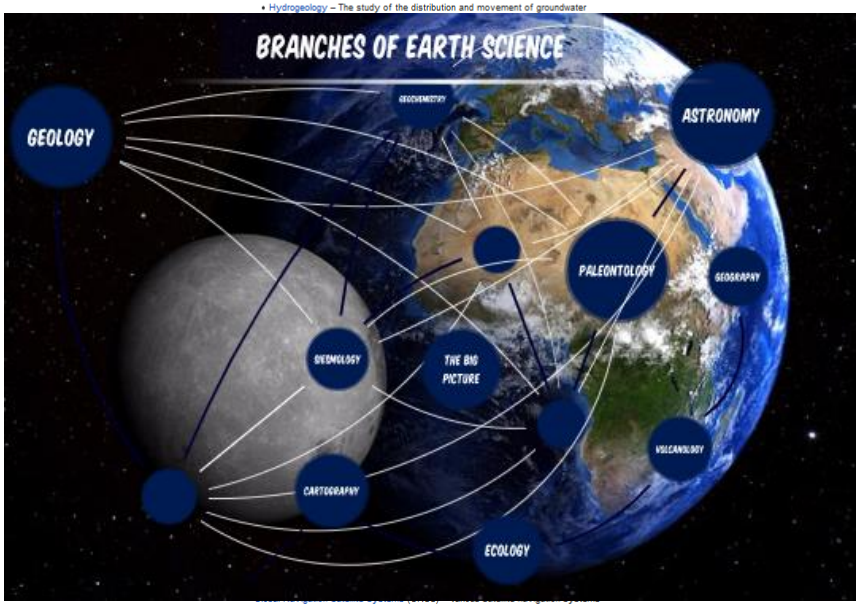
Atmospheric science [edit]

Atmospheric sciences – The study of the atmosphere, its processes, and interactions with other systems

- Climatology – The scientific study of climate, defined as weather conditions averaged over a period of time
- Paleoclimatology – The study of changes in climate taken on the scale of the entire history of Earth
- Atmospheric chemistry – The branch of atmospheric science in which the chemistry of the atmosphere is studied
- Atmospheric physics – The application of physics to the study of the atmosphere
- Paleotempestology – The study of past tropical cyclone activity using geological proxies and historical documents

Geology [edit]

- Geology – The study of the composition, structure, physical properties, and history of Earth's components, and the processes by which th
  - Environmental geology – Science of the practical application of geology in environmental problems.
  - Quaternary geology – The branch of geology that studies developments more recent than 2.6 million years ago
  - Planetary geology – The geology of astronomical objects apparently in orbit around stellar objects
  - Petroleum geology – The study of the origin, occurrence, movement, accumulation, and exploration of hydrocarbon fuels
  - Historical geology – The study of the geological history of Earth
  - Hydrogeology – The study of the distribution and movement of groundwater



- Economic geology – Science concerned with earth materials of economic value.
- Engineering geology – The application of the geology to engineering practice.
- Hydrology – The science of applying engineering techniques to the properties of the earth's water, especially its movement in relation to lar
- Meteorology – Interdisciplinary scientific study of the atmosphere focusing on weather forecasting.
- Satellite navigation – Any system that uses satellite radio signals to provide. autonomous geo-spatial positioning
- Remote sensing – Acquisition of information at a significant distance from the subject.
- Photogrammetry – The science of making measurements using photography.

Oceanography [edit]

Oceanography – The study of the physical and biological aspects of the ocean

- Biological oceanography – The study of how organisms affect and are affected by the physics, chemistry, and geology of the oceanograp
- Physical oceanography – The study of physical conditions and physical processes within the ocean
- Chemical oceanography – The study of ocean chemistry
- Paleoceanography – The study of the history of the oceans in the geologic past
- Limnology – The science of inland aquatic ecosystems
- Marine geology – The study of the history and structure of the ocean floor

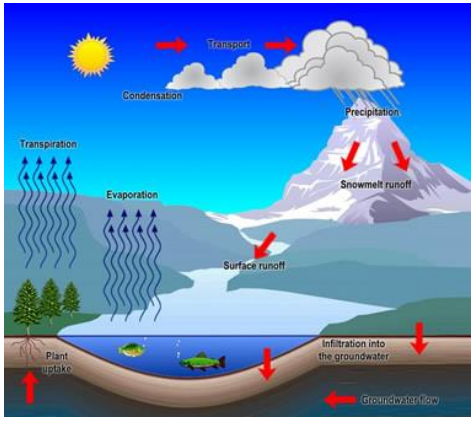
Planetary science [edit]

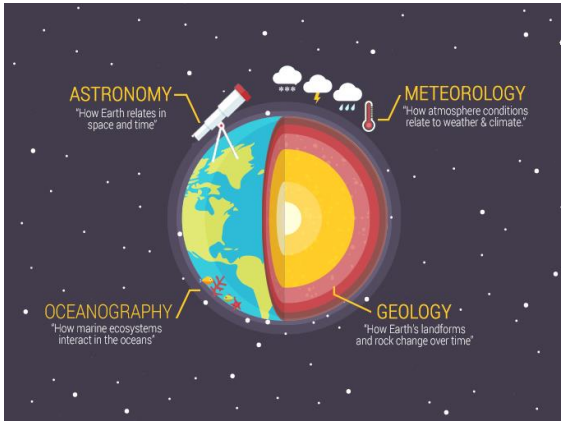
Planetary science – The study of planets (including Earth), moons, and planetary systems (in particular those of the Solar System) and the pr

- Planetary geology - study of the geology of astronomical objects apparently in orbit around stellar objects
- Selenography - study of the surface and physical features of the Moon
- Theoretical planetology - the theoretical study of the internal structure of planets by making assumptions about their chemical composition

Aims of course

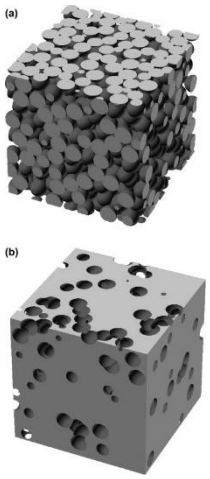
- Introduction to selected areas of geoscience and (geo-)engineering
- Basics of application of computational methods and theoretical solutions in cooperation with other experts
- You should finally
  - Recognize the physical principles in practical situations
  - Distinguish simple and complex problems
  - Understand the need in (input) data and evaluate their availability and accuracy

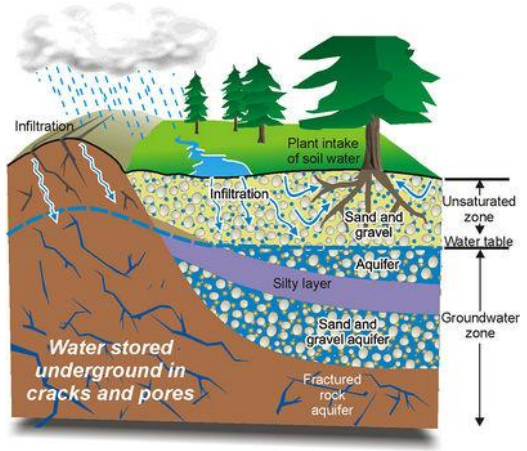


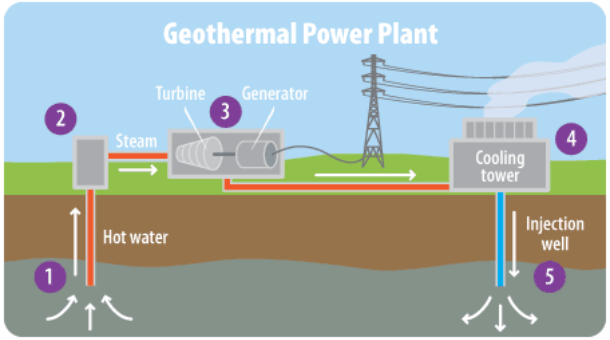


Processes in rock materials (study fields)

- Phenomena
  - Rock/soil: porous medium
  - Mechanics (stress/deformation)
  - Heat
  - Groundwater
  - Chemical reactions (water-rock)
- Applications
  - Water resources, contamination/remediation, civil engineering (tunnels), mining, geothermal energy, spent nuclear fuel disposal

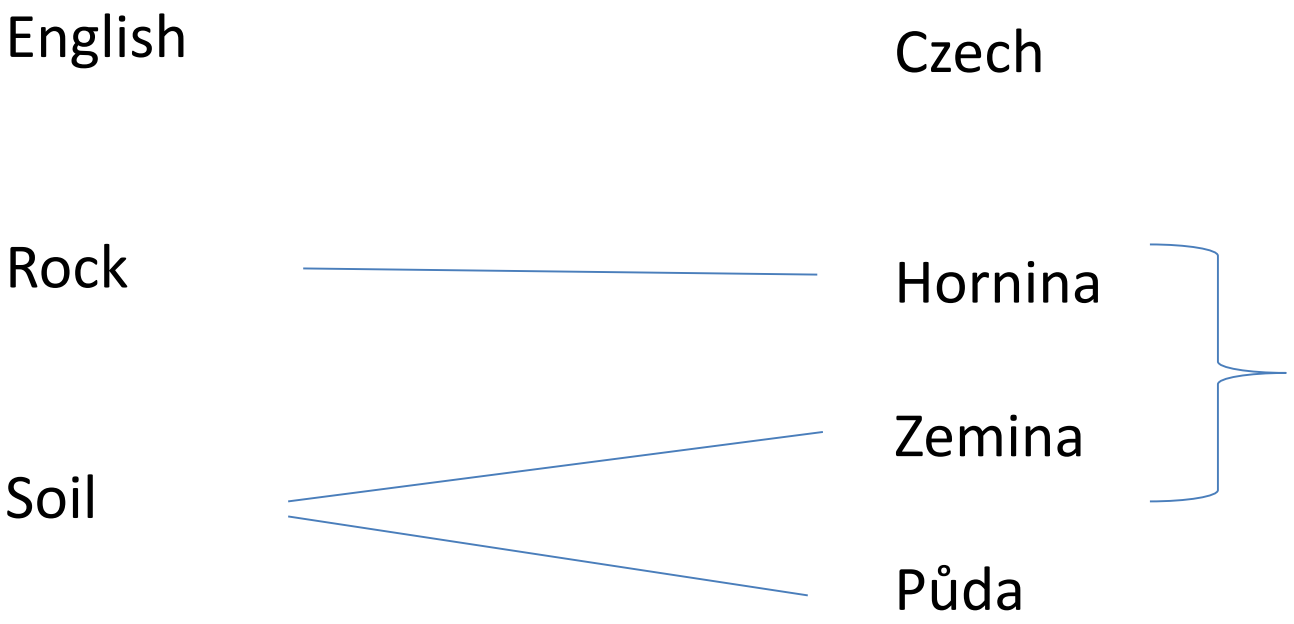






Terminology (context-dependent)

- Earth sci. / engineering / life sci (agriculture)



Course schedule

- Water flow in porous media
- Solute transport (dissolved species)
- Intro to heat transport and elasticity (compared to common material)
- Methods of laboratory and field measurement (overview)
- Coupled phenomena
- Fractures (discontinuities)

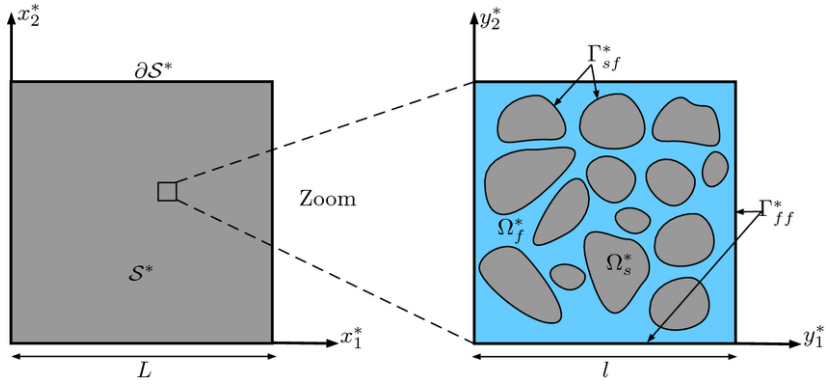
Porous medium

- Solid phase grains
- Free space (pores), filled with fluid (gas/liquid)

Microscopic view
= heterogenetity

„Homogenization“

Macroscopic view
= continuum



Continuum Microscopic

Definition of quantities in homogenized concept

Macroscopic quantity

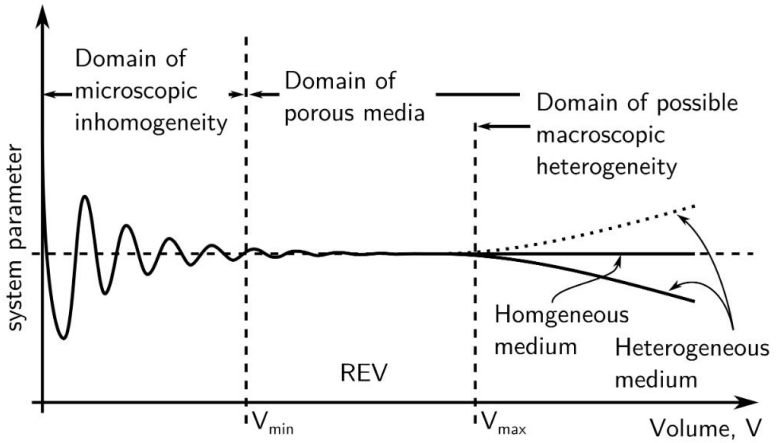
$$\alpha = \frac{1}{V}\int_{V} \alpha^{\mathrm{mic}}\,\mathrm{d}V$$

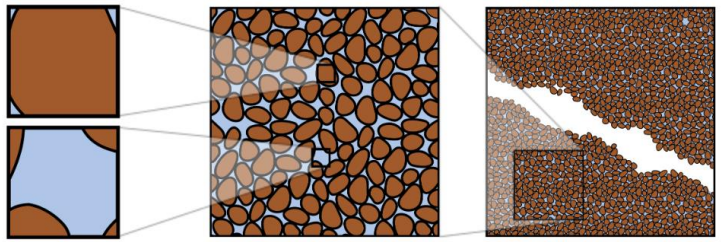
Average over point neighbourhood

Condition:
Pore dimension much less than body dimensions

REV = representative elementary volume
- Enough small wrt problem scale
- Enough large wrt pore scale

Condition for validity of homogenization





Porosity (cz: Pórovitost)

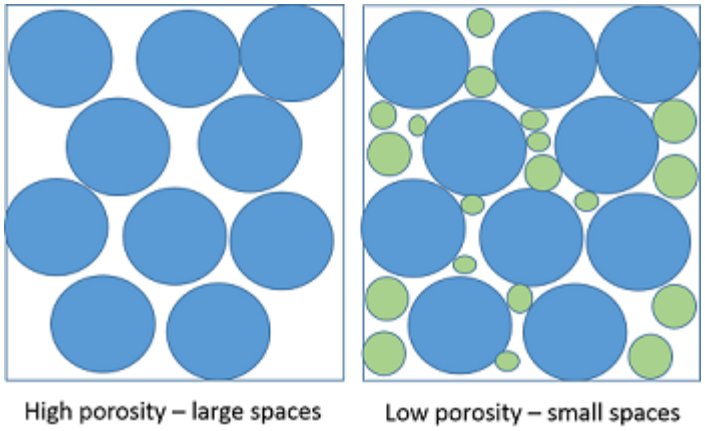
Pore volume / body volume

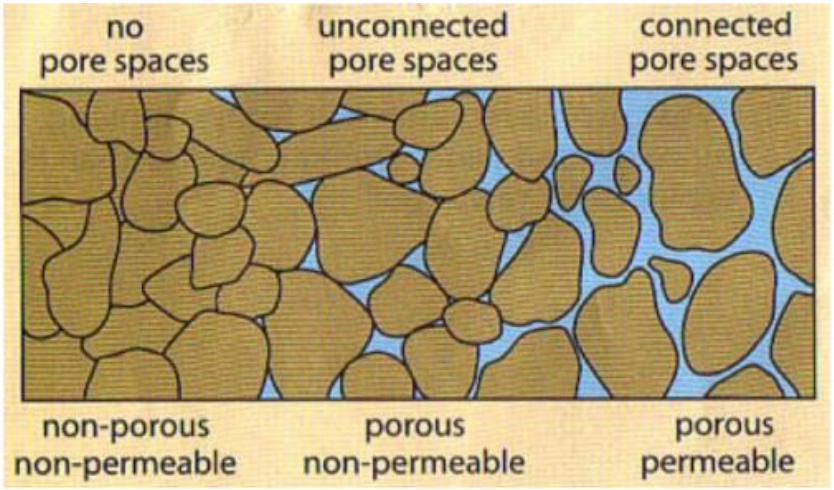
$$n = \frac{V(pores)}{V(porous\ body)}$$

(In homogenized sense)

$0 < n < 1$
$0 < n < 100\%$

Typical natural materials: n<0.4





Example values

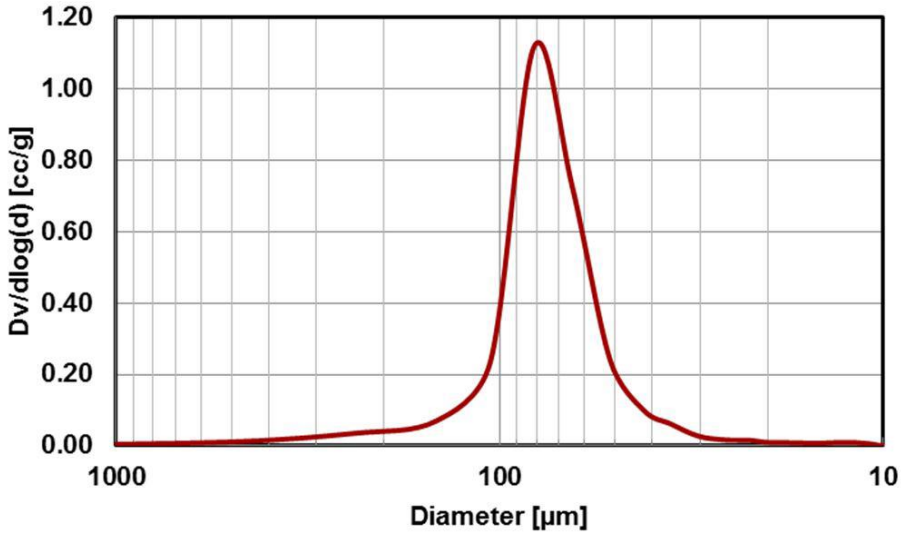
Soil Type	Porosity, p_t
Unconsolidated deposits	
Gravel	0.25 - 0.40
Sand	0.25 - 0.50
Silt	0.35 - 0.50
Clay	0.40 - 0.70
Rocks	
Fractured basalt	0.05 - 0.50
Karst limestone	0.05 - 0.50
Sandstone	0.05 - 0.30
Limestone, dolomite	0.00 - 0.20
Shale	0.00 - 0.10
Fractured crystalline rock	0.00 - 0.10
Dense crystalline rock	0.00 - 0.05

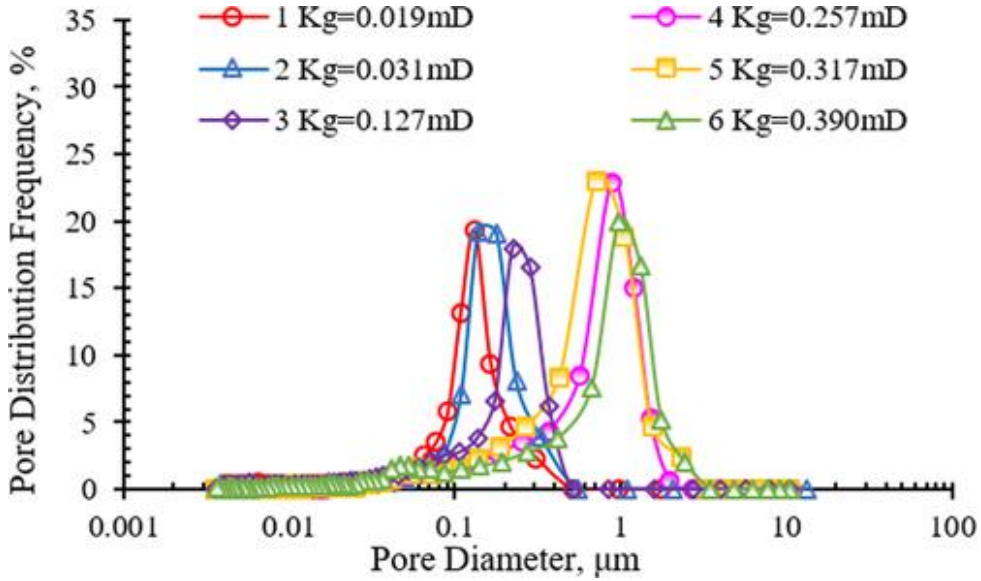
Other soil parameters

- Dry density (CZ: suchá objemová hmotnost, objemová hmotnost sušiny)
- Solid density

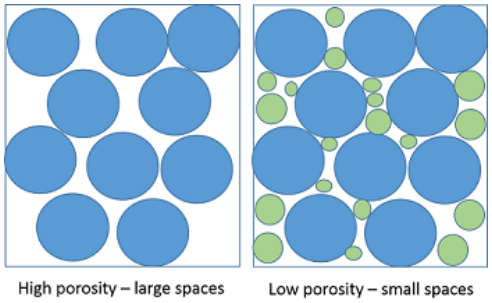
- Void ratio (CZ: číslo pórovitosti)

Pore size distribution



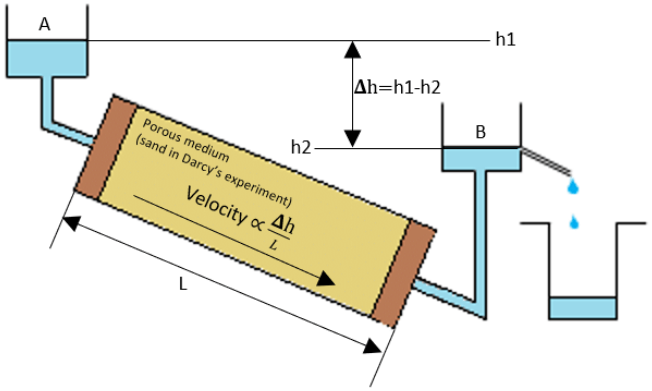


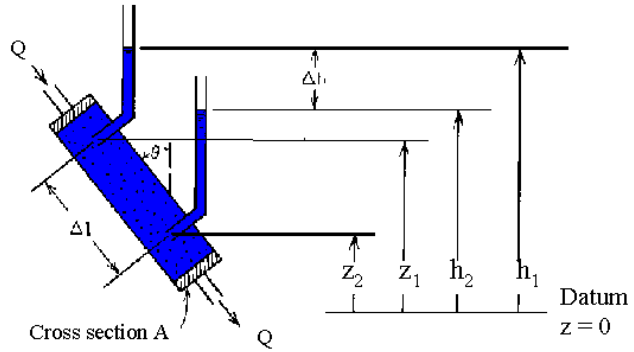
"Narrow" versus "wide" size distribution



Water flow in porous media

- Darcy's experiment (1856)





Experimental apparatus for the illustration of Darcy's law.
After Freeze and Cherry, 1979

$$Q = K \cdot \frac{S \cdot (h_1 - h_2)}{L}$$

$$[\mathrm{m}^3/\mathrm{s}] \quad [\mathrm{m}/\mathrm{s}] \; \frac{[\mathrm{m}^2][\mathrm{m}]}{[\mathrm{m}]}$$

Darcy's Law, quantities

$$Q = K \cdot \frac{S \cdot (h_1 - h_2)}{L}$$

$[\mathrm{m}^3/\mathrm{s}]$ $[\mathrm{m}/\mathrm{s}]$ $\frac{[\mathrm{m}^2][\mathrm{m}]}{[\mathrm{m}]}$

Hydraulic conductivity

$$q = \frac{Q}{S} = K \cdot \frac{(h_1 - h_2)}{L}$$

$[\mathrm{m}/\mathrm{s}]$ $[\mathrm{m}/\mathrm{s}]$ $[1]$

"velocity"

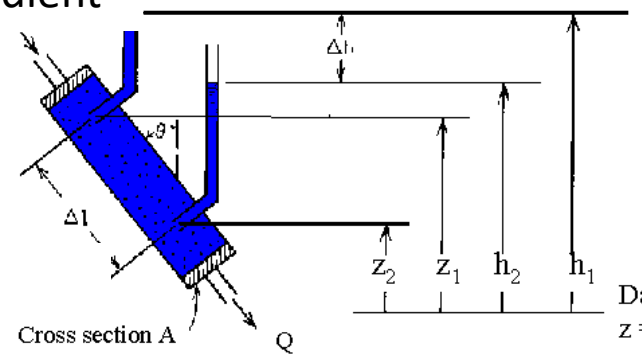
Hydraulic gradient

$$p_1 = \varrho g(h_1 - z_1)$$

$$p_2 = \varrho g(h_2 - z_2)$$

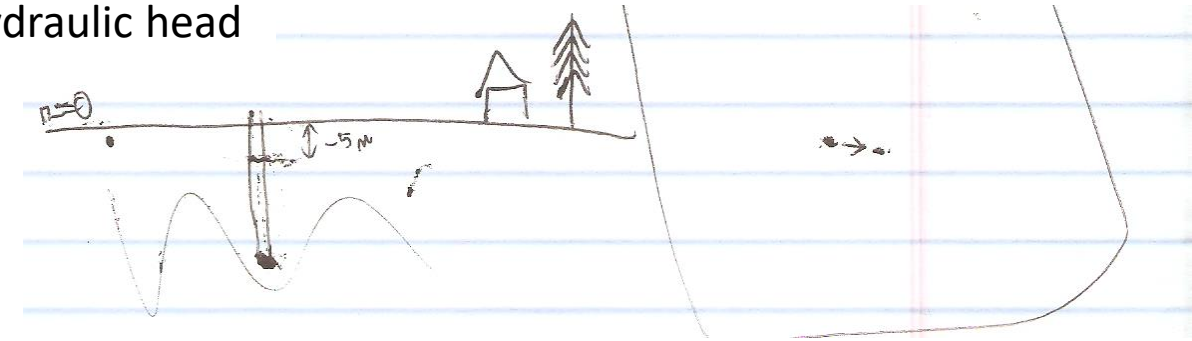
$$h = z + \frac{p}{\varrho g}$$

gravity pressure



Experimental apparatus for the illustration of Darcy's law.
After Freeze and Cherry, 1979

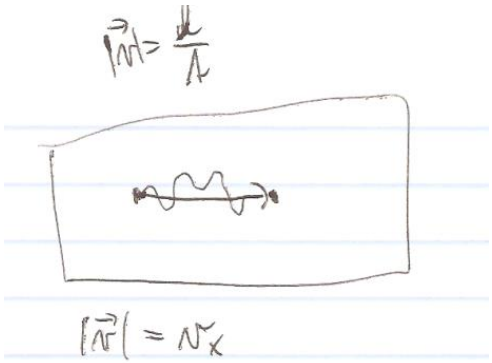
h … Piezometric/hydraulic head



Water flow velocity

$$\boldsymbol{v} = \frac{1}{V_{REV}^{w}} \int_{V_{REV}^{w}} \boldsymbol{v}^{(mic)} \mathrm{d}V^{w}$$

Water/pore volume

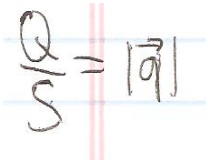


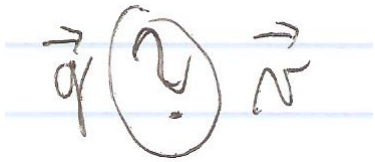
v … Particle movement from point to point

$$\boldsymbol{q} = \frac{1}{V_{REV}} \int_{V_{REV}} \boldsymbol{v}^{(mic)} \mathrm{d}V$$

Total volume

q … Amount of water (across unit area]





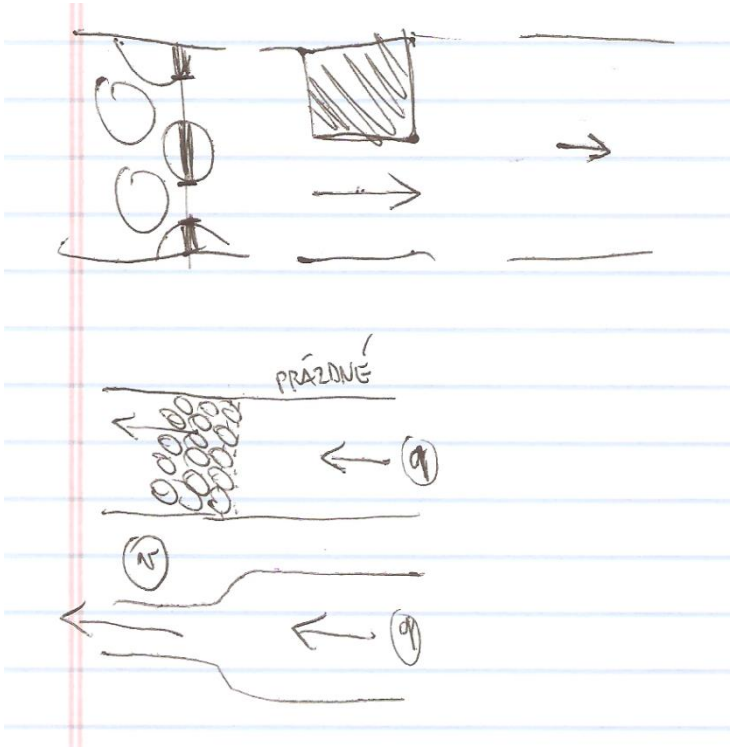
Comparison

$$q\,S = v\,S\,n$$

$$q = v\,n$$

$$v = \frac{q}{n}$$

$$v > q$$



q … “Darcy velocity”
(flow rate density)

v … (average) pore velocity