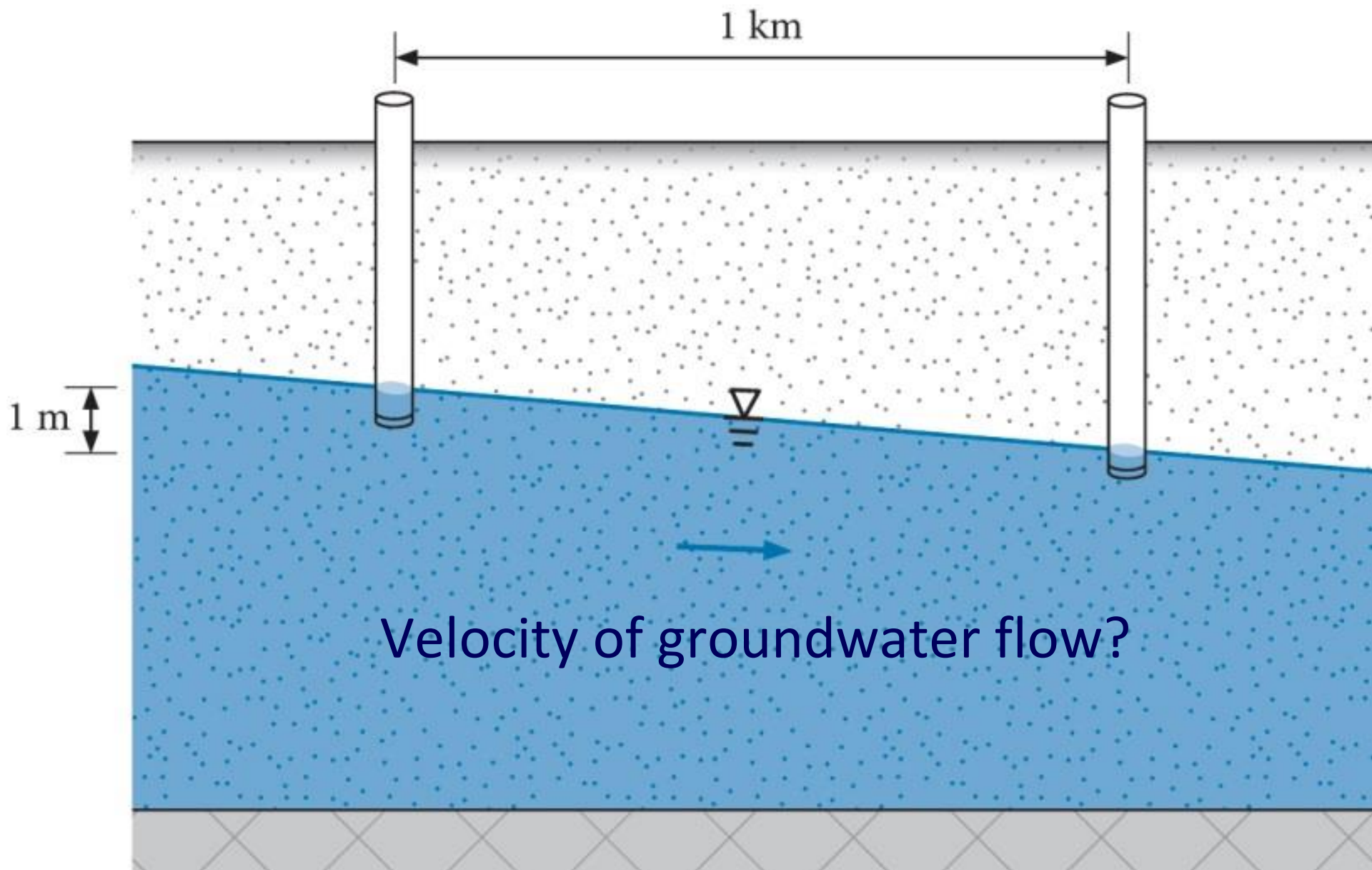
Darcy's law



Multiple choice question

By law of nature, water flows from high to low

A. elevation

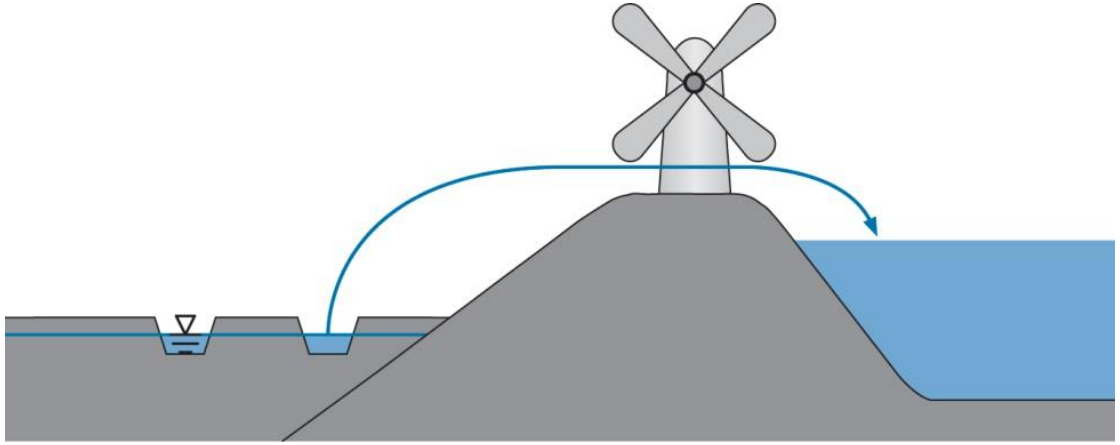
B. energy

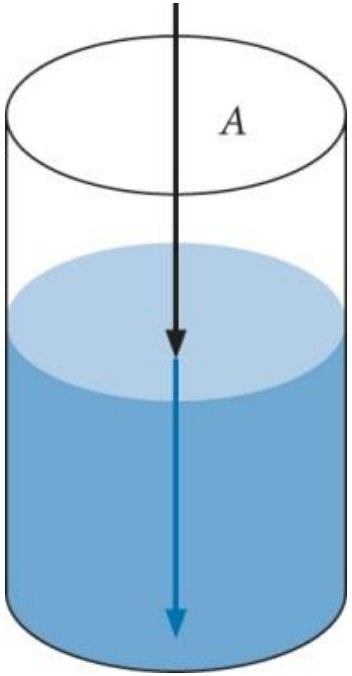
C. pressure

D. All of the above options are true

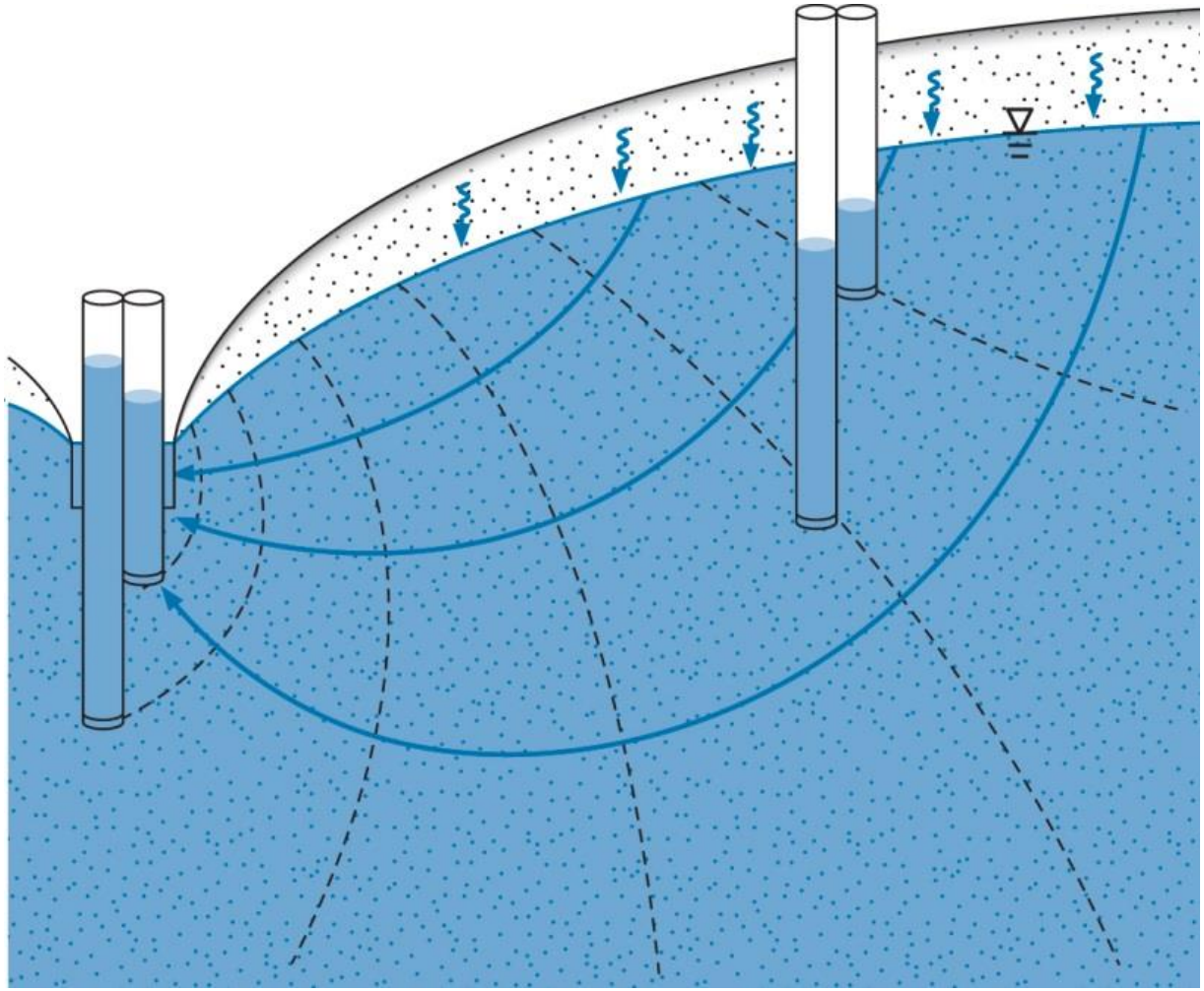
Model between two glass plates

Misconceptions





Unconfined groundwater



Pennink (1853-1936)

Bernoulli's law

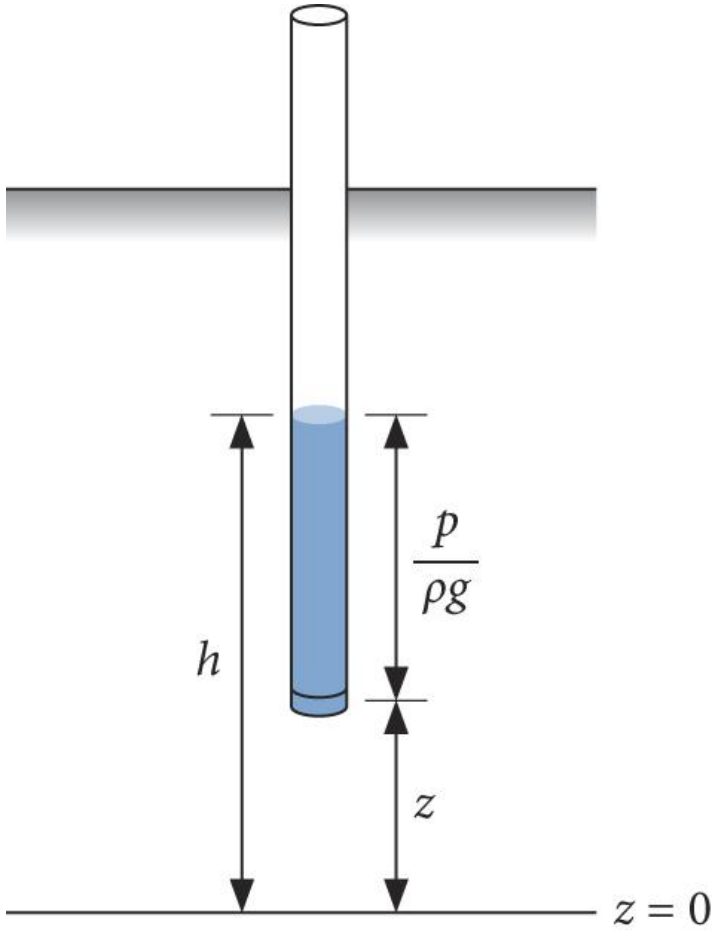
$$mgz + pV = \text{constant}$$

$$\rho g z + p = \text{constant}$$

$$z + \frac{p}{\rho g} = \text{constant}$$

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

Bernoulli's law



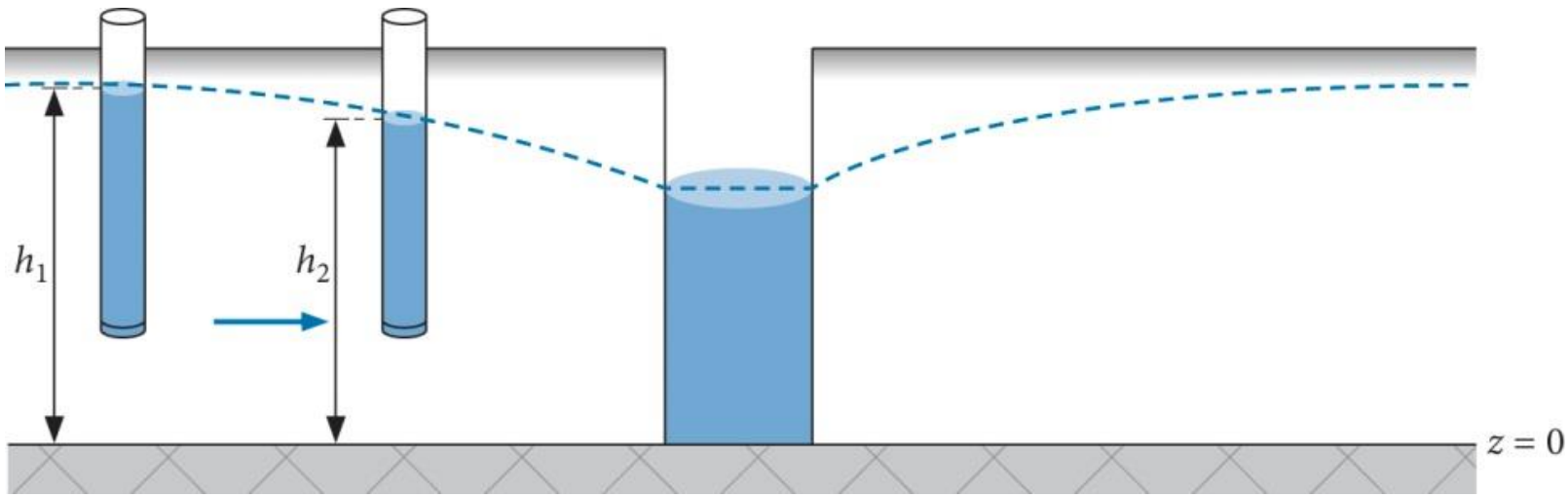
$$h = z + \frac{p}{\rho g}$$

Hydraulic head (stijghoogte)

Elevation head (plaatshoogte)

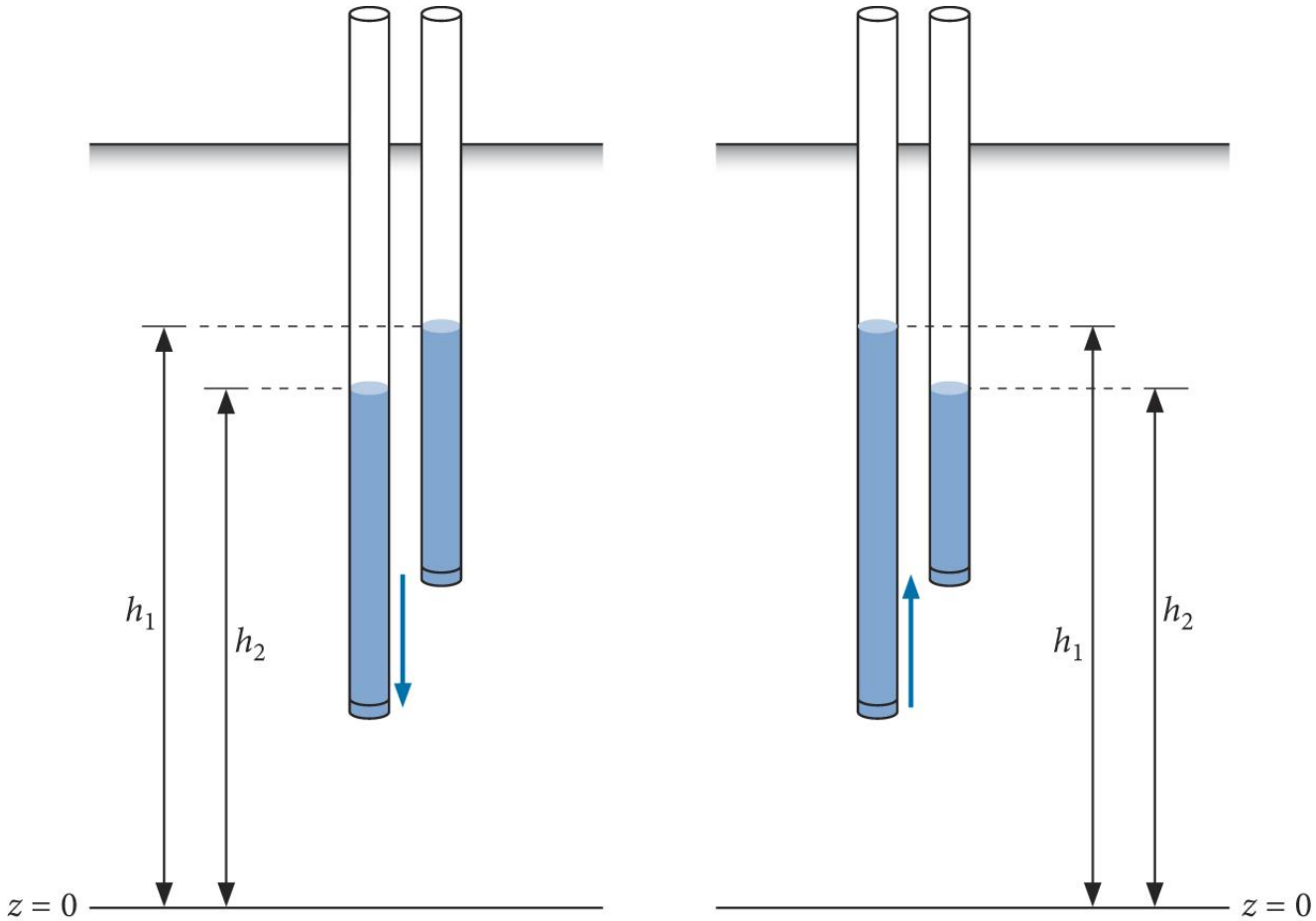
Pressure head (drukhoogte)

Horizontal groundwater flow



Groundwater flow is in the direction of the lower hydraulic head h_2

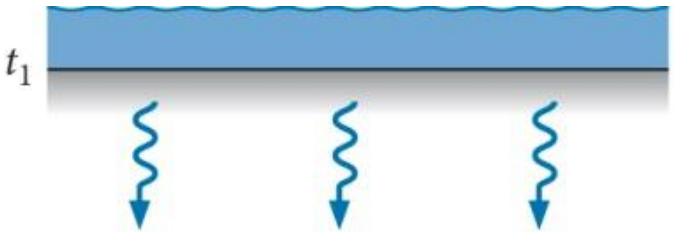
Vertical groundwater flow



Downward seepage

Upward seepage

Effective velocity and volume flux density



$$P = 5\,\text{mm hour}^{-1}$$

$$\text{Depth} = 15\,\text{mm}$$

$$n_e = \tfrac{1}{3}$$

$$v_e = 15\,\text{mm hour}^{-1}$$

$$q = 5\,\text{mm hour}^{-1}$$

$$v_e = \frac{q}{n_e}$$

Effective velocity and volume flux density

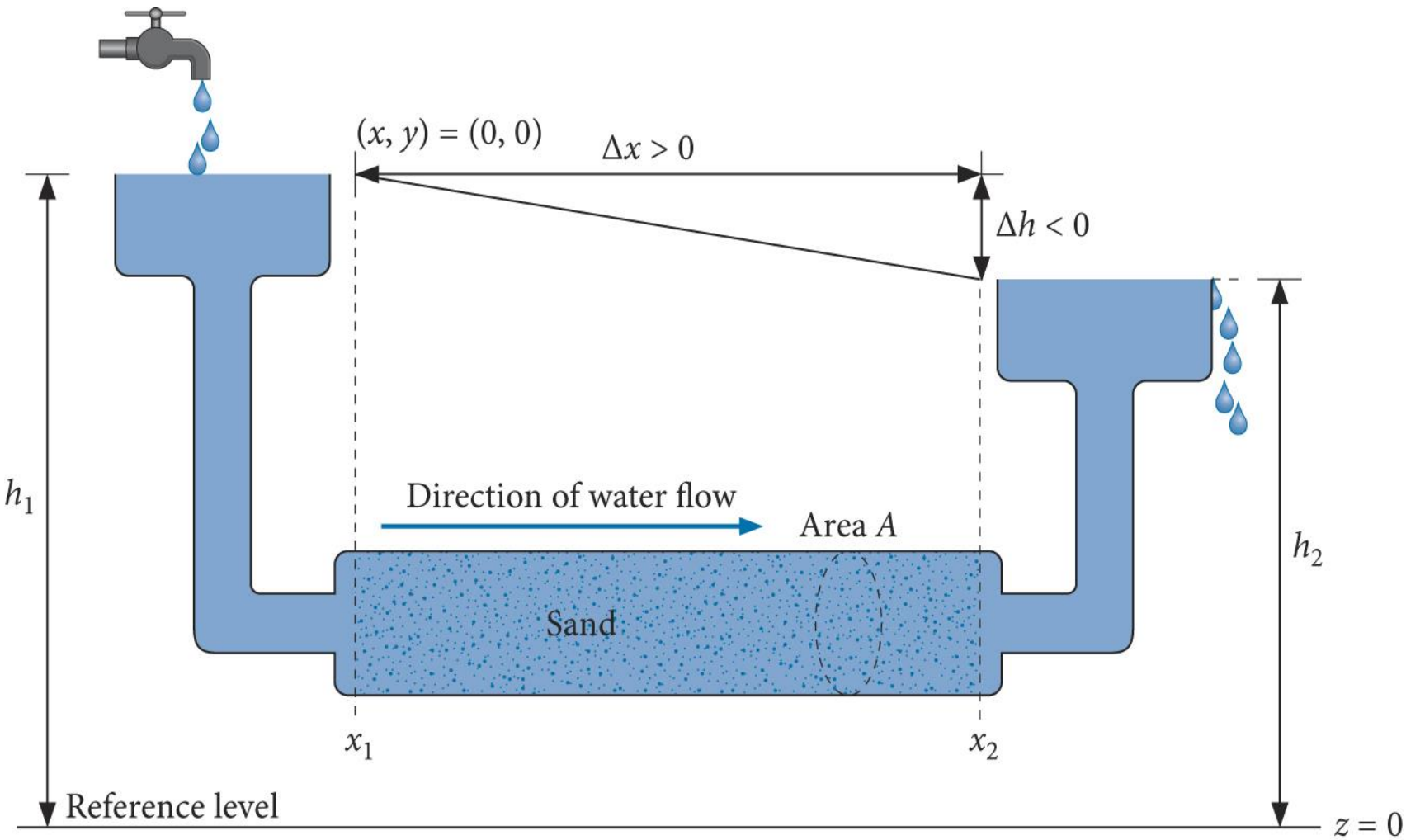
Rainfall intensity	$P = 5\,\text{mm hour}^{-1}$
Infiltration depth	$\text{Depth} = 15\,\text{mm}$
Effective porosity	$n_\text{e} = \frac{1}{3}$
Effective velocity	$v_\text{e} = 15\,\text{mm hour}^{-1}$

Volume flux density or specific discharge

$$q = 5\,\text{mm hour}^{-1}$$

$$v_\text{e} = \frac{q}{n_\text{e}}$$

Volume flux or discharge Q



Volume flux or discharge Q

$$(h_1 - h_2)\uparrow$$

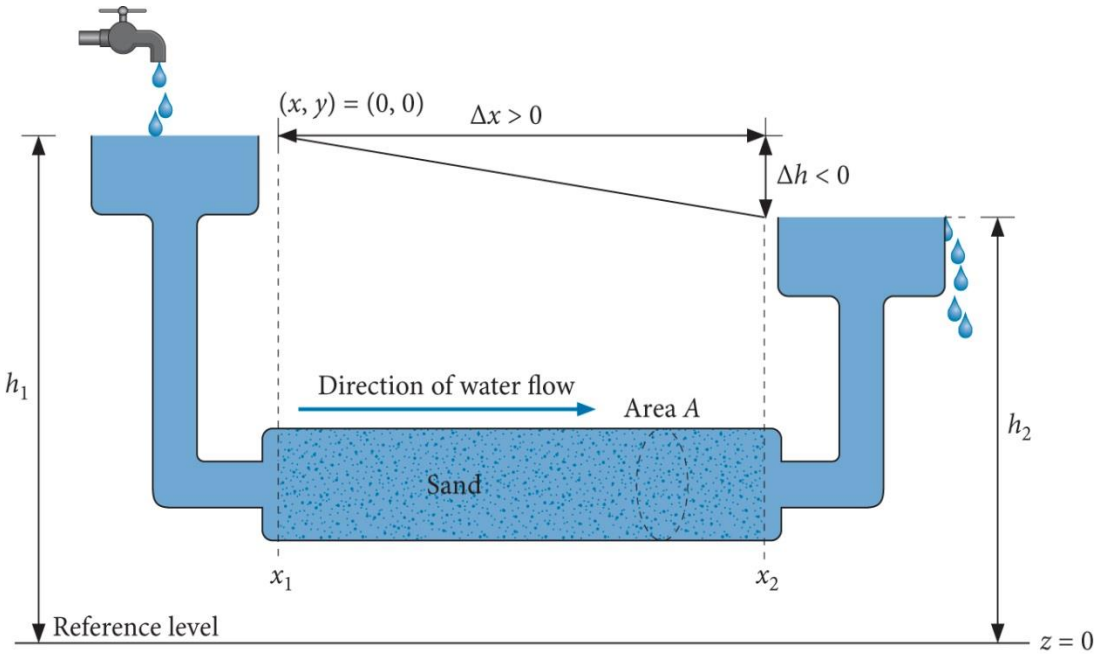
$$(h_1 - h_2)\uparrow \Rightarrow Q\uparrow$$

$$(x_2 - x_1)\downarrow$$

$$(x_2 - x_1)\downarrow \Rightarrow Q\uparrow$$

$$A\uparrow$$

$$A\uparrow \Rightarrow Q\uparrow$$



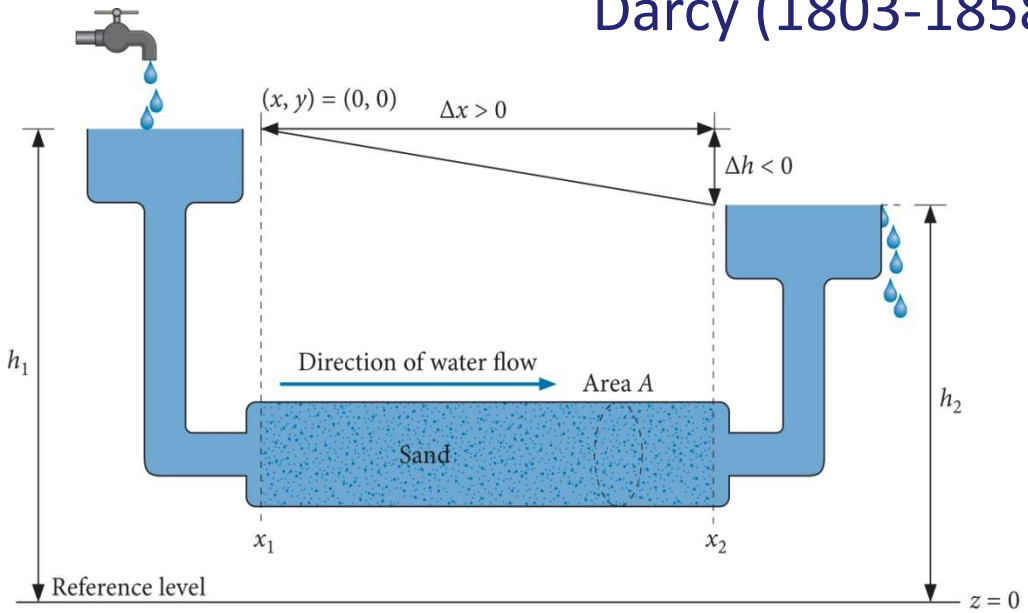
$$Q \approx \frac{h_1 - h_2}{x_2 - x_1} A$$

Darcy's law

Darcy (1803-1858)

$$Q \approx \frac{h_1 - h_2}{x_2 - x_1} A$$

$$Q \approx -\frac{h_2 - h_1}{x_2 - x_1} A = -i\,A$$



$$Q = -K\,i\,A$$

Hydraulic conductivity K (m day^{-1})

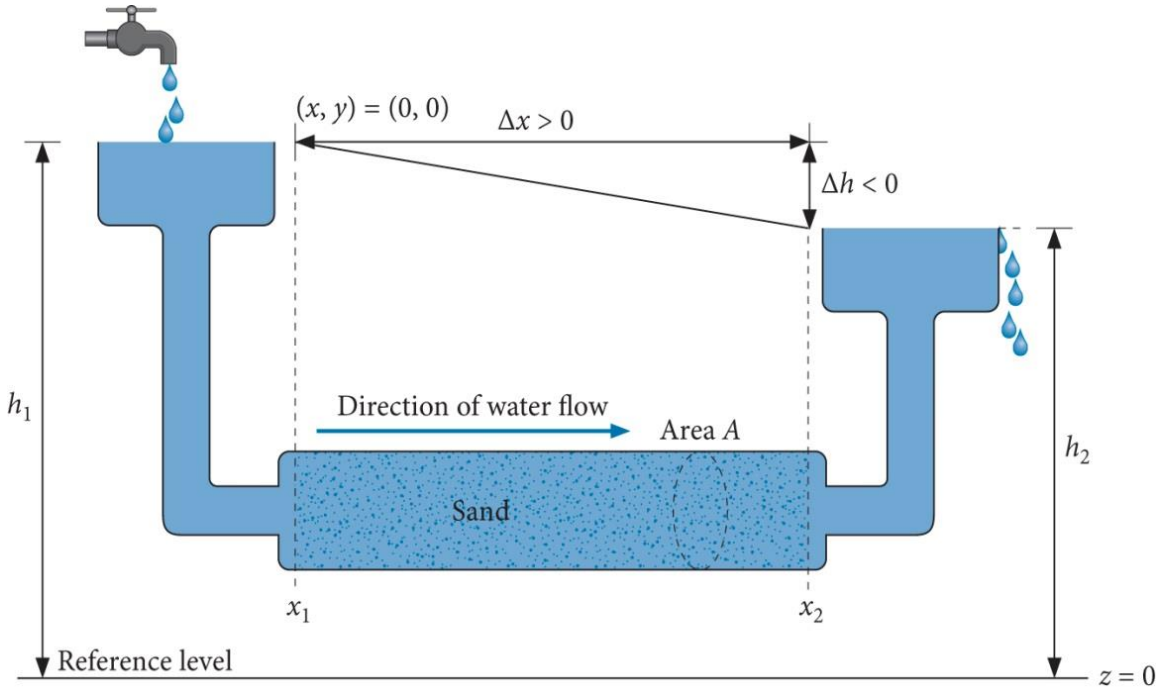
$$q = \frac{Q}{A} = -K\,i$$

Darcy's law and effective velocity

$$Q = -K\,i\,A$$

$$q = \frac{Q}{A} = -K\,i$$

$$v_e = \frac{q}{n_e}$$

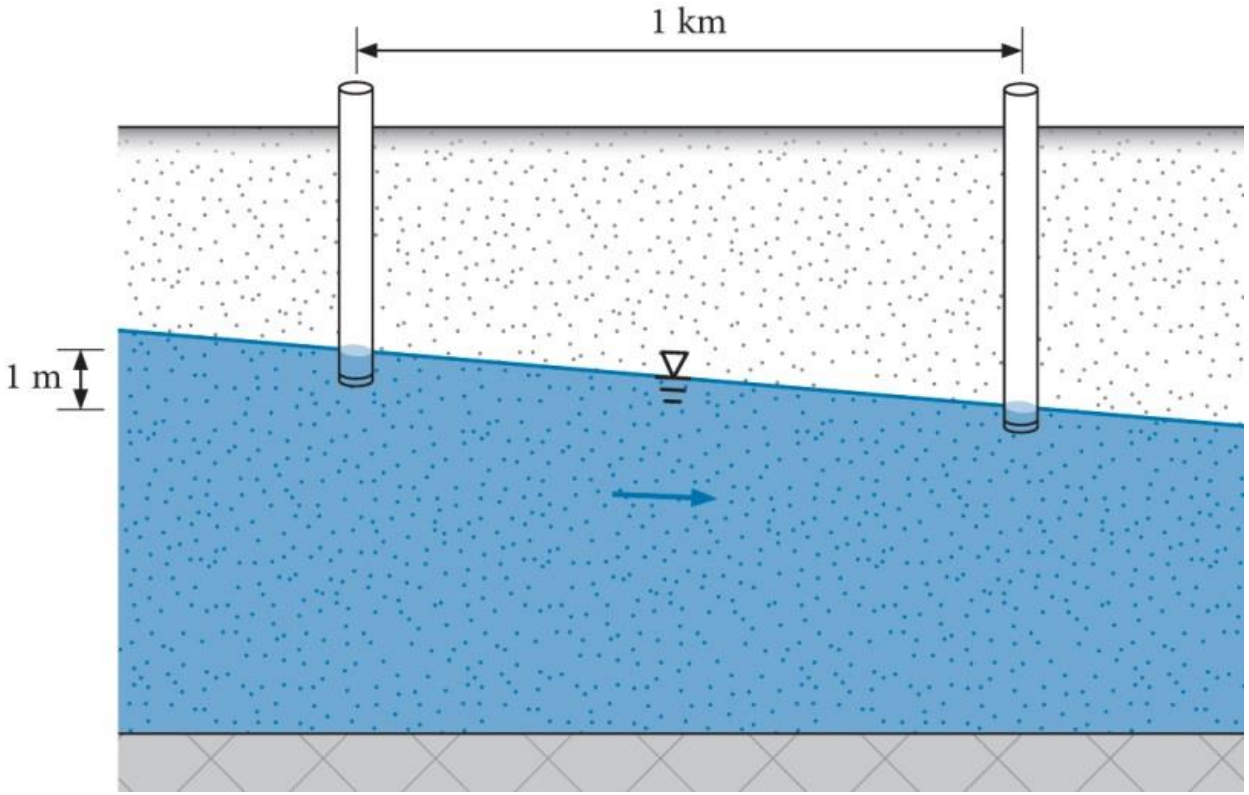


Volume flux or discharge Q ($m^3\ day^{-1}$)

Volume flux density or specific discharge q ($m\ day^{-1}$)

Effective groundwater velocity v_e ($m\ day^{-1}$)

Velocity of groundwater flow



$$q = -K\,i = -10 \times -10^{-3} = 10^{-2}\ \text{m day}^{-1}$$

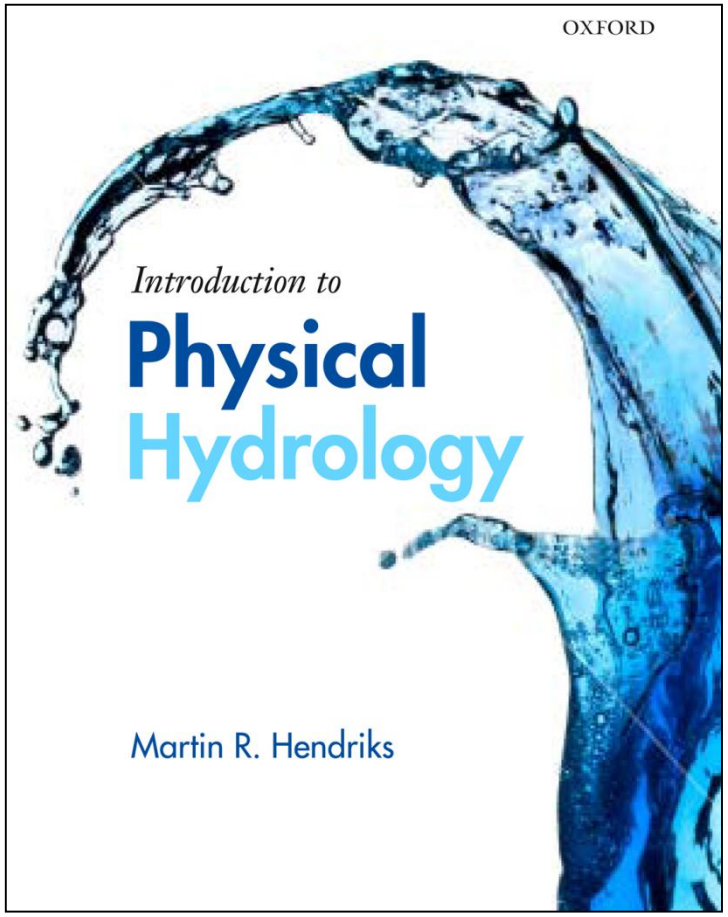
$$v_e = \frac{q}{n_e} = \frac{10^{-2}}{0.4} = 2.5 \times 10^{-2}\ \text{m day}^{-1} = 2.5\ \text{cm day}^{-1}$$

Multiple choice question

By law of nature, water flows from high to low

energy

Introduction to Physical Hydrology



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- Drainage basin
- Water balance

- Energy equation
- Flow equation
- Continuity equation

1. Introduction
2. Atmospheric water
3. Groundwater
4. Soil water
5. Surface water

Exercises