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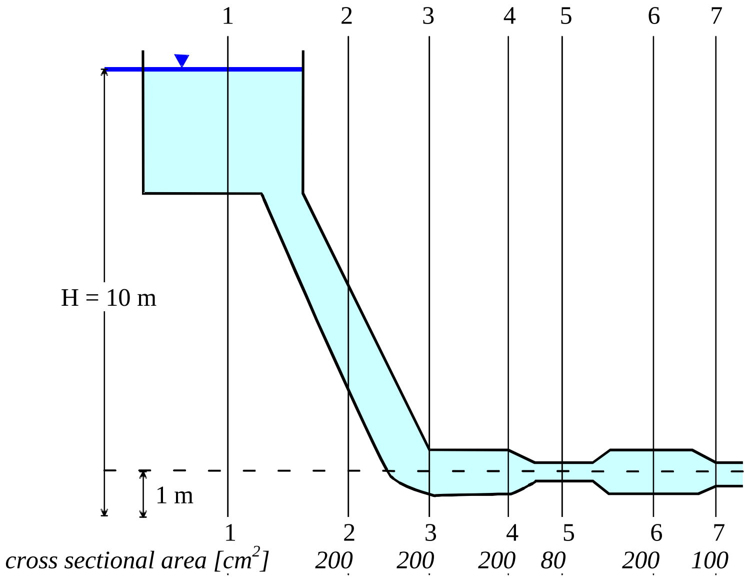
## EXERCISE 6

Water is flowing from a water tower into piping of different cross sectional areas, before it leaves the system at point 7.

Cross sectional areas of pipes:

$F_2 = F_3 = F_4 = F_6 = 200\ cm^2$ $F_5 = 80\ cm^2$ $F_7 = 100\ cm^2$

What is the hydraulic head, the flow velocity, the pressure head and the elevation head at each point of the pipe network? (Hint: Use the Bernoulli and the continuity equation)




$$H = \frac{v^2}{2g} + z + \frac{p}{\rho g}$$

Ideal, frictionless fluid → no energy lost!

$\Rightarrow H_1 = H_2 = .... = H_7 = const = 10$ m (initial head at point 1 = total head)

**Position 7**: Water leaves pipeline → pressure head drops to zero: $\frac{p}{\rho g} = 0$,

elevation head = 1 m:

$$H_7 = \frac{{v_7}^2}{2g} + z_7 + 0$$

$$v_7 = \sqrt{2g(H_{7(=1)} - z_7)}$$

$v_7 = \underline{13,28\ m/s} \Rightarrow Q = v_7\,F_7 = 0,1328\ m^3/s$

Continuity equation:

$\Rightarrow Q = v_1\,F_1 = v_2\,F_2 = v_3\,F_3 = v_{......}\,F_{......} = v_7\,F_7$

$\Rightarrow v_2\,F_2 = v_7\,F_7$

$\Rightarrow v_2 = v_7\,F_7\,/F_2 = \underline{6.65\ m/s}$

Because: $F_2 = F_3 = F_4 = F_6 \Rightarrow v_2 = v_3 = v_4 = v_6 = 6.65$ m/s

$v_5 = v_7F_7/F_5 = \underline{16.60\ m/s}$

c) pressure head = total head – velocity head – elevation head

$$h = H - \frac{v^2}{2g} - z$$

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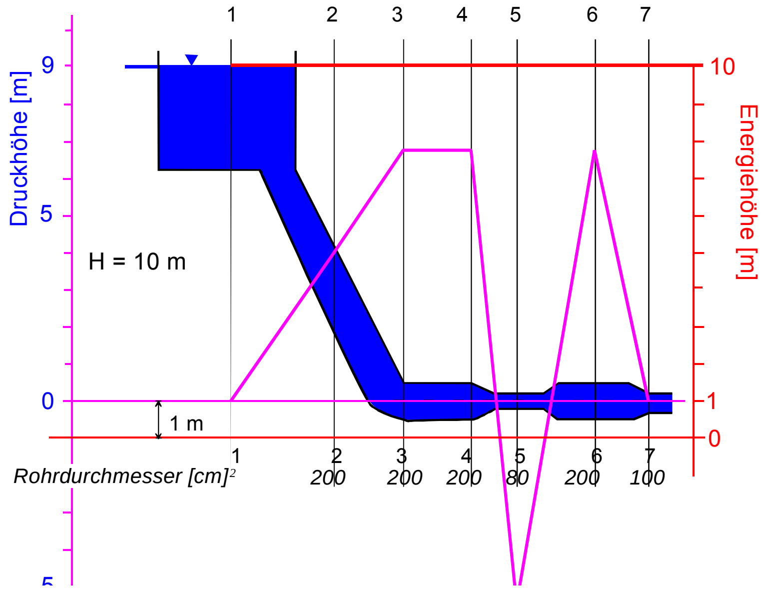
$h_{p1}$ = 10 - 0 - 10 = 0

$h_{p7}$ = 0

$h_{p2}$ =10 – $6.65^2/(2*9.81)$ - 5 = 2.75 m

$h_{p3}$, $h_{p4}$, $h_{p6}$ = 10 - $6.65^2/(2*9.81)$ -1 = 6.75 m

$h_{p5}$ = 10 -$16.6^2/(2*9.81)$ -1= -5,04 m




## EXERCISE 7

The following parameters were measured in a constant head permeameter test:

$\Delta$h = - 5 cm $\Delta$l = 10 cm

Cross sectional area A = 100 cm2 Duration of experiment t = 1 h

Volume of percolated water after 1 h: V = 3,6 l

a) What is the hydraulic conductivity of the sample?

b) What is the darcy velocity and the linear velocity, if the sample (porosity 0.2) is representative for an aquifer (hydraulic gradient dh/dL= - 0.0025)?

$Q = k_f \, I \, A \Rightarrow k_f = Q/(I*A)$

$$Q = 3.6 \text{ l in } 1 \text{ h} = = \frac{3.6 \bullet 10^{-3} \text{ m}^3}{60 \bullet 60 \text{ s}} = \underline{1 * 10^{-6} \text{ m}^3/\text{s}}$$

$A = 100 \text{ cm}^2 = 0{,}01 \text{ m}^2$

$$I = \frac{Dh}{Dl} = \frac{5 \text{ cm}}{10 \text{ cm}} = 0{,}5$$

$$k_f = \frac{1 \bullet 10^{-6} \text{ m}^3/\text{s}}{0.5 \bullet 0.01 \text{ m}^2} = 2 * 10^{-4} \text{ m/s} \rightarrow \text{sand}$$

Darcy velocity

$$v_f = \frac{Q}{F} \Rightarrow v_f = k_f * I \Rightarrow v_f = 2 * 10^{-4} \text{ m/s} * 0.0025 = 5.0 * 10^{-7} \text{ m/s}$$

Linear velocity:

$$v_n = v_a = \frac{v_f}{n_e} = 2.5 * 10^{-6} \text{ m/s}$$

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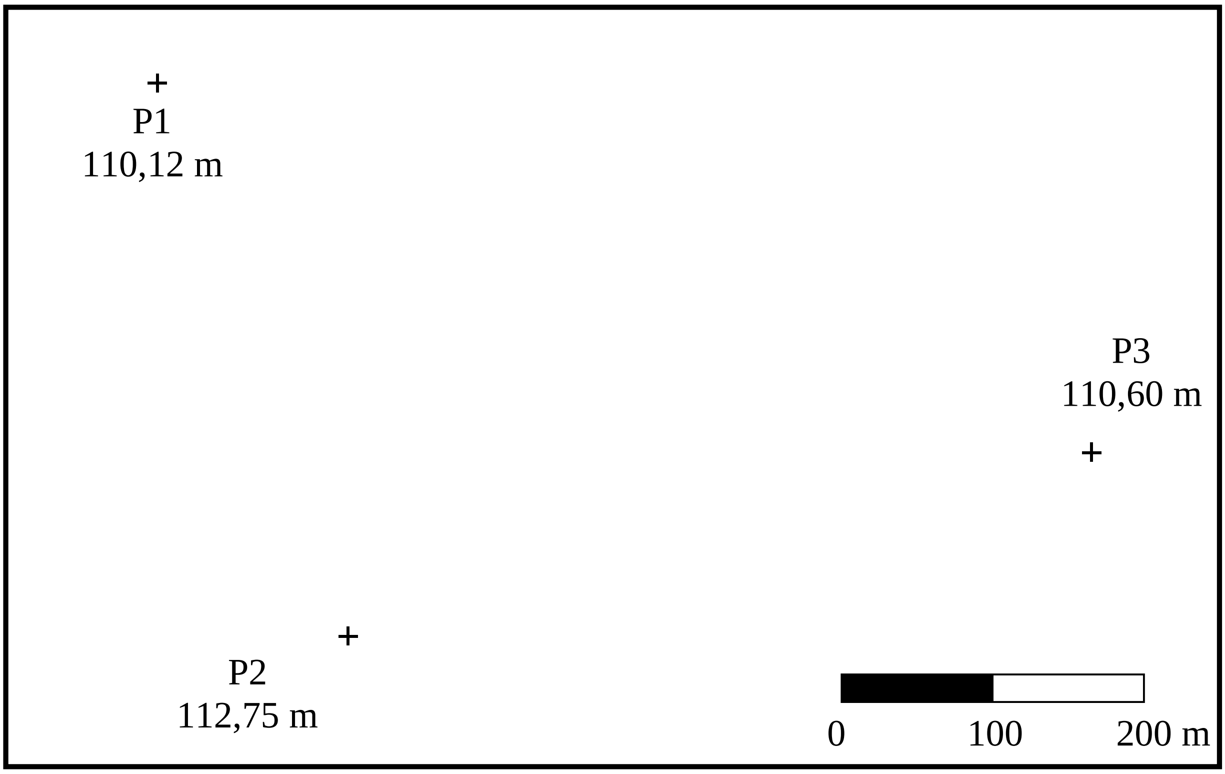
## EXERCISE 8

Unconfined, homogeneous porous aquifer with 3 observation wells.




| Grain size [mm] | Total finer **[g]** |
|---|---|
| 63 | 0 |
| 31.5 | 25 |
| 16 | 190 |
| 8 | 200 |
| 4 | 210 |
| 2 | 190 |
| 1 | 90 |
| 0.5 | 40 |
| 0.25 | 20 |
| 0.125 | 15 |
| 0.063 | 12 |
| <0.063 | 8 |

a) Draw the grain size distribution curve.

b) Calculate the hydraulic conductivity and the uniformity coefficient.

c) Draw a map of the potentiometric surface (1m isolines, triangulation) and calculate the specific discharge (Darcy velocity) in the aquifer.

A:

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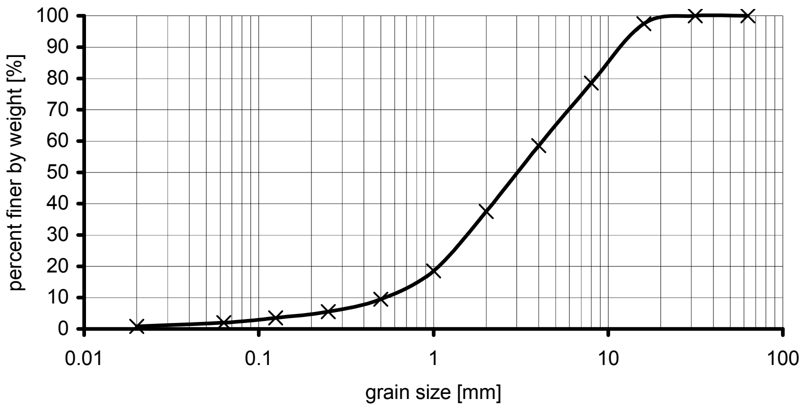
| Grain size [mm] | Total finer [g] | Mass fraction [%] | Percent finer by weight [%] |
|---|---|---|---|
| 0,02 | 8 | 0,8 | 0,8 |
| 0,063 | 12 | 1,2 | 2 |
| 0,125 | 15 | 1,5 | 3,5 |
| 0,25 | 20 | 2 | 5,5 |
| 0,5 | 40 | 4 | 9,5 |
| 1 | 90 | 9 | 18,5 |
| 2 | 190 | 19 | 37,5 |
| 4 | 210 | 21 | 58,5 |
| 8 | 200 | 20 | 78,5 |
| 16 | 190 | 19 | 97,5 |
| 31,5 | 25 | 2,5 | 100 |
| 63 | 0 | 0 | 100 |
| Sum | 1000 | 100 | |




B:

$d_{10} = 0.5$ mm; $d_{60} = 4.2$ mm $\Rightarrow U = \frac{d_{60}}{d_{10}} = 8.4$

after Hazen Zischang (C=0.0116) : $k_f = 5.8E\text{-}5$ m/s;

C: q = Ki

**EXERCISE 9**

The following water levels were measured in a 20 m thick homogeneous, isotropic porous aquifer (representative grain size distribution curve given below).

a. Draw the water table contour (1 m isopiestic lines).
b. Determine the hydraulic conductivity.
c. Calculate the specific discharge and the linear flow velocity.

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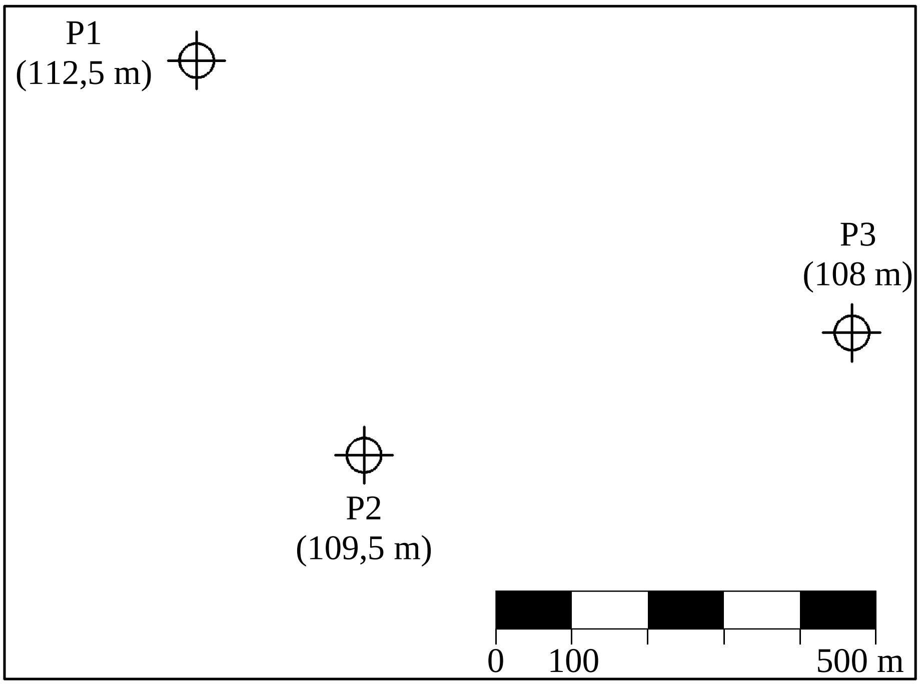
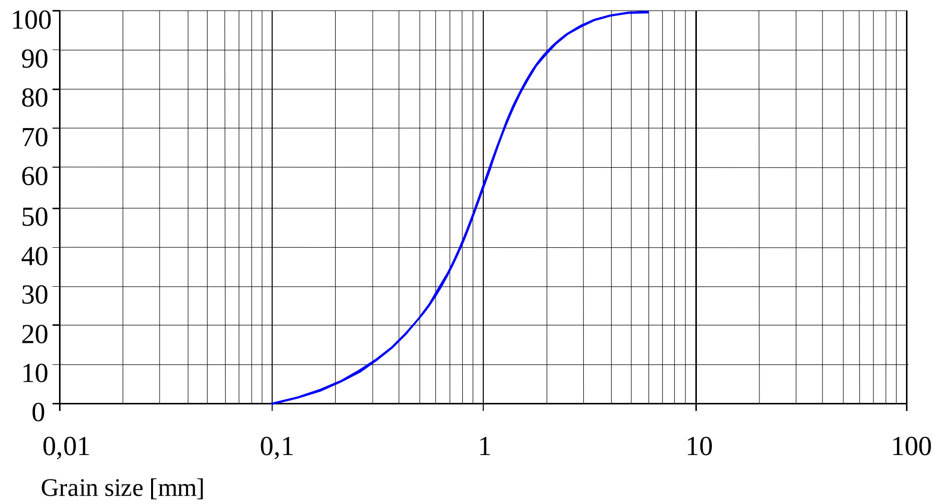
d. Calculate the discharge per day for cross-section of 100 m width (perpendicular to the isopiestic lines).




(a) Draw contours

(b) Draw grain size distribution




□x(between 112 m and 111 m isopiestic lines) = 190 m and Δh = -1 m

I = -Δh/Δx = 1/190 m = 0.00526

Hydraulic conductivity:

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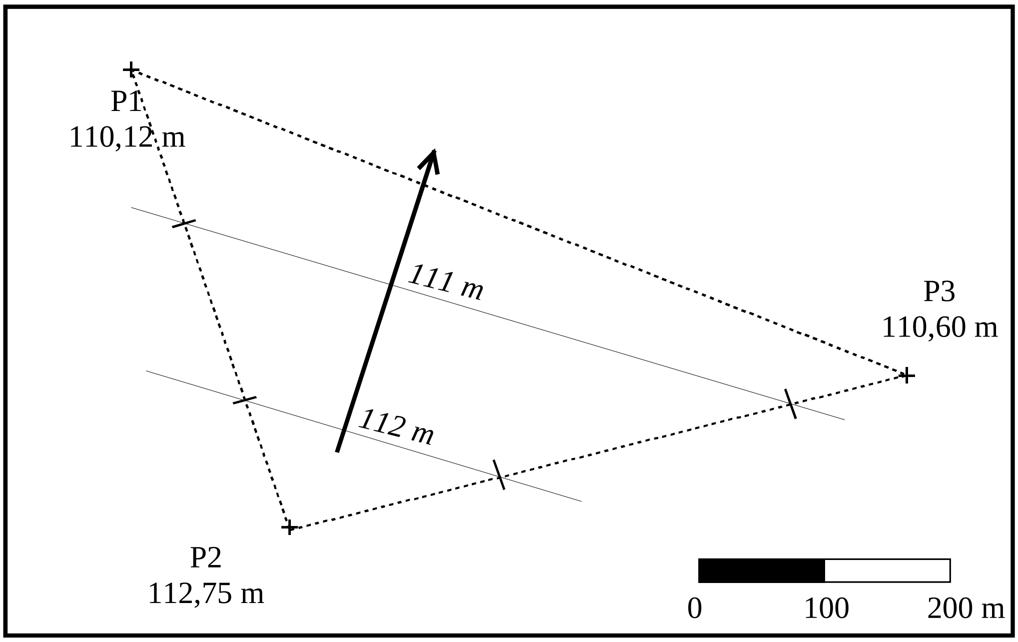
$K = C * d_{10}^2 * (0.79 + 0,03 * T)/86.4$ [m/s] = $0.0093 * 0.3^2 * (0.79 + 0.03 * 14)/86.4$ m/s = 1.17E-5 m/s

(c) v = K * I = 6.15E-8 m/s

Q = K*A*I=1.17E-5 m/s *100 m*20 m*0.00526 = 1.1231E-4 $m^3/s$ = 10.634 $m^3$/24 hrs




$$I = \frac{112\ m - 111\ m}{120\ m} = 0.0083$$

$v_f = k_f * I$ = 4.87E-5 m/s *0.0083 = 4.06 E-7 m/s