UNIVERSITY OF AGDER

FACULTY OF ENGINEERIGN AND SCIENCE

E X A M

Course code: **ENE410**
Course name: **Fluid Dynamics and Hydro Power**

Date: December 5, 2016
Duration: 4 hours

Number of pages incl. front page: 9

Resources allowed: All written and handwritten material, pocket calculator

Notes: 6 problems

EXAM ENE410 – Fluid Dynamics and Hydro Power

Problem 1

A recorded series of maximum values of instantaneous (peak) discharge is given in the table below. Knowing that Gumbel's law is the statistical law that best fits the data series, compute:

a) the maximum peak discharge for the return period of 100 years;

b) the return period corresponding to a peak discharge of 841.8 m^3/s.

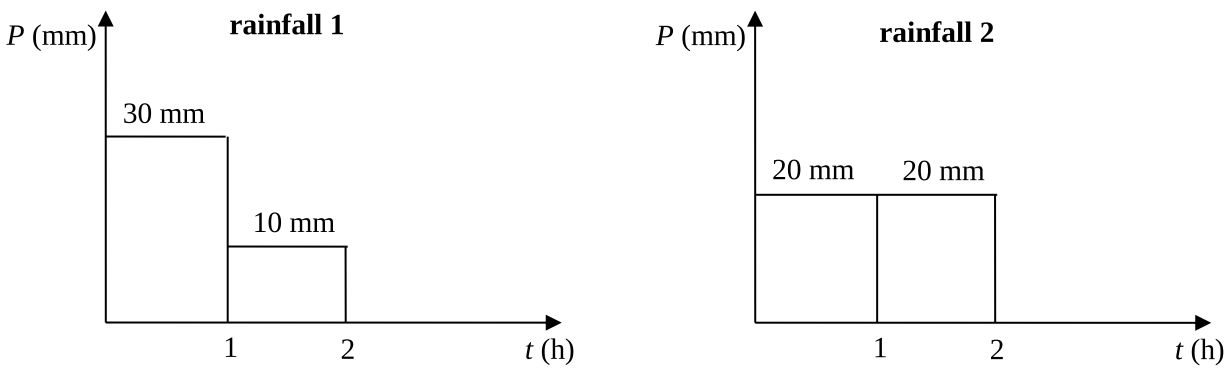
Year	Peak discharge (m^3/s)
2002/03	1000
2002/06	950
2002/12	900
2002/05	800
2002/09	750
2002/08	700
2002/04	650
2002/07	600
2002/11	500
2002/10	300

Problem 2

A unit hydrograph corresponding to a unitary precipitation (1 mm) with duration equal to 1 hour is presented in the table.

UNIT HYDROGRAPH	
Time **t (h)**	**Discharge** **Q (m^3/s)**
0	0
1	10
2	20
3	15
4	10
5	5
6	0

Two rainfall events (rainfall 1 and 2) with same total duration (2 hours) and amount of precipitation (40 mm) have the following temporal distributions.



Determine which rainfall event originates the maximum peak discharge.

Problem 3

A hydropower plant uses, under a constant net head of 30.5 m, a discharge between 8.5 m^3/s and 28.3 m^3/s. In these conditions, determine:

a) the most appropriate turbine and the minimum operating efficiency;

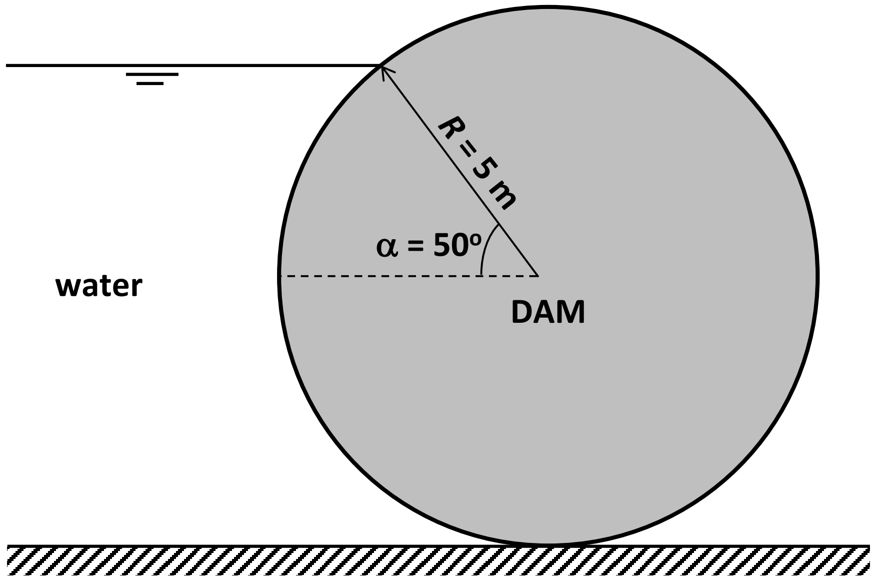
b) the turbine main characteristics (n_s, n, p and $P_{turbine}$).

Problem 4

A cylindrical inflatable rubber dam with 5 m radius and 20 m wide is installed on a river, creating a water reservoir on its left side and having no water on the right side (see figure). In these conditions determine:

a) the horizontal impulsion (hydrostatic force) on the dam;

b) the vertical impulsion (hydrostatic force) on the dam.

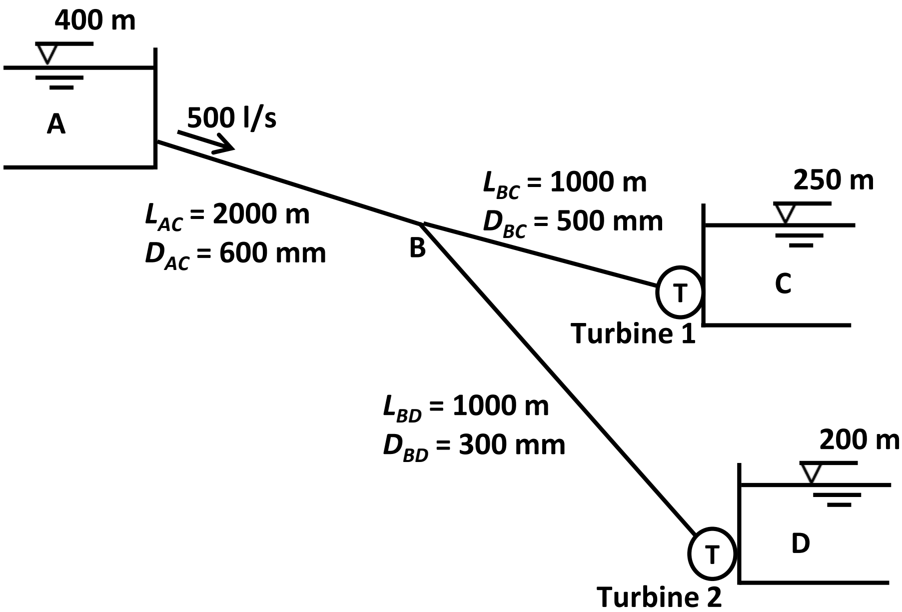


Problem 5

Reservoir A can supply turbines 1 and 2 (both with efficiency equal to 80%). Turbine 1 discharges into reservoir C and turbine 2 discharges into reservoir D. All pipes are made of cast iron ($Q = 30.4 D^{2.633} S_f^{0.51}$). All information concerning the reservoir levels and the length and diameter of the conduits are given in the figure. The discharge from reservoir A is equal to 500 l/s. Neglecting the minor head losses and assuming $\alpha = 1$, determine:

a) the net head and power of turbine 1 when turbine 2 is not operating;

b) the discharges used in turbine 1 and turbine 2 (i.e. Q_{BC} and Q_{BD}) for having a total power $P_{\text{turbine 1}} + P_{\text{turbine 2}}$ = 580 kW, maintaining the discharge from reservoir A equal to 500 l/s.



Problem 6

A hydropower system has a conveyance channel connecting the intake to a forebay, as shown in the figure. The discharge is controlled by a vertical sluice gate (A) in the intake. The gate has a contraction coefficient of 0.7. The levels in the intake and in the forebay are constant. The conveyance channel has a rectangular cross-section with 3 m width, is made of concrete (n = 0.01 $m^{-1/3}s$) and has a length of 3.2 km, which is long enough to reach uniform flow conditions. In these conditions:

a) determine the opening of the gate to have a discharge of 10 m^3/s (assume that the flow depth downstream the gate is the one of the vena contracta, i.e. that if an hydraulic jump occurs downstream the gate it is free);

b) verify if channel AB has mild or steep slope and if the assumption of a free hydraulic jump downstream the gate is correct;

c) determine the flow depths upstream and downstream the hydraulic jump;

d) draw qualitatively the free-surface profile along the channel indicating the types of gradually varying flow (GVF) curves.

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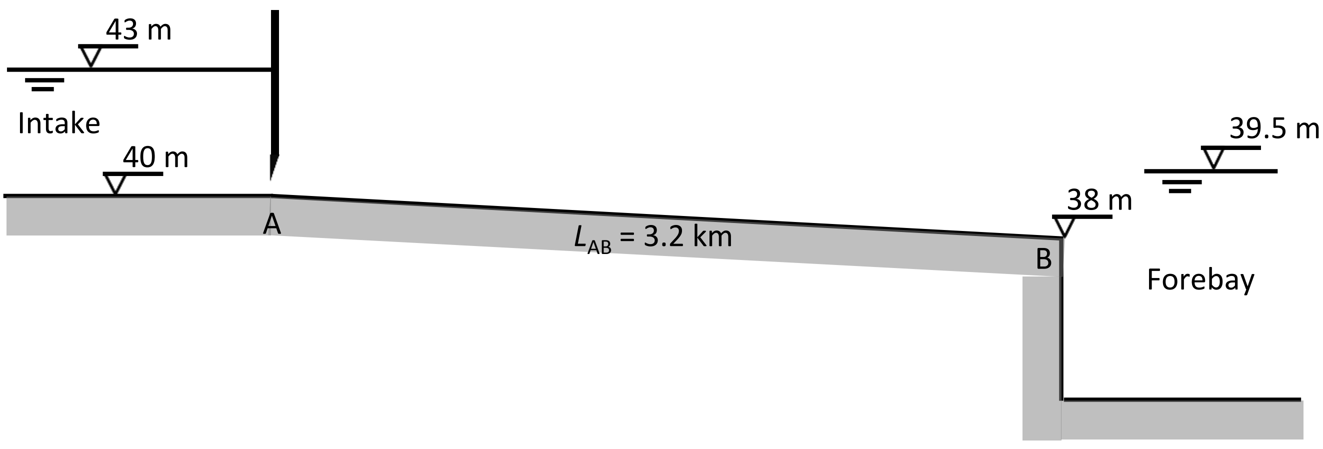

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Formulae

$\pi = \gamma A h_0$ $\quad p_{atm}^{absolute} = 1.01325\times 10^5\ \text{Pa}$ $\quad \frac{p}{\gamma} + z = constant$

$X = x_0 + \frac{I_{GG'}}{A x_0}$ $\quad \pi_h = \gamma A_{proj} h_{0\,proj}$ $\quad \pi_v = \gamma \forall$ $\quad \mathrm{Re} = \frac{UD}{\nu}$

$\vec{M}_{in} - \vec{M}_{out} + \vec{I} + \vec{G} + \vec{\pi} = 0$ $\quad H = \frac{p}{\gamma} + z + \alpha \frac{U^2}{2g}$ $\quad h_f = f \frac{L}{D} \frac{U^2}{2g}$ $\quad h_f = S_f L$

$H_2 = H_1 - h_f - h_m$ $\quad \frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\varepsilon}{3.7D} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right)$ $\quad h_m = K \frac{U^2}{2g}$

$P_t = \eta P_{flow} = \eta\gamma Q H_{net}$ $\quad P_{pump} = \frac{P_{flow}}{\eta} = \frac{\gamma Q H_t}{\eta}$ $\quad E = h + \alpha \frac{U^2}{2g}$

$h_c = \sqrt[3]{\frac{Q^2}{g b^2}}$ $\quad R_h = \frac{A}{P}$ $\quad Q = \frac{1}{n} S R_h^{2/3} S_f^{1/2}$ $\quad Q_0 = \sqrt{g}\, S(h_c) \sqrt{\frac{S(h_c)}{b(h_c)}}$

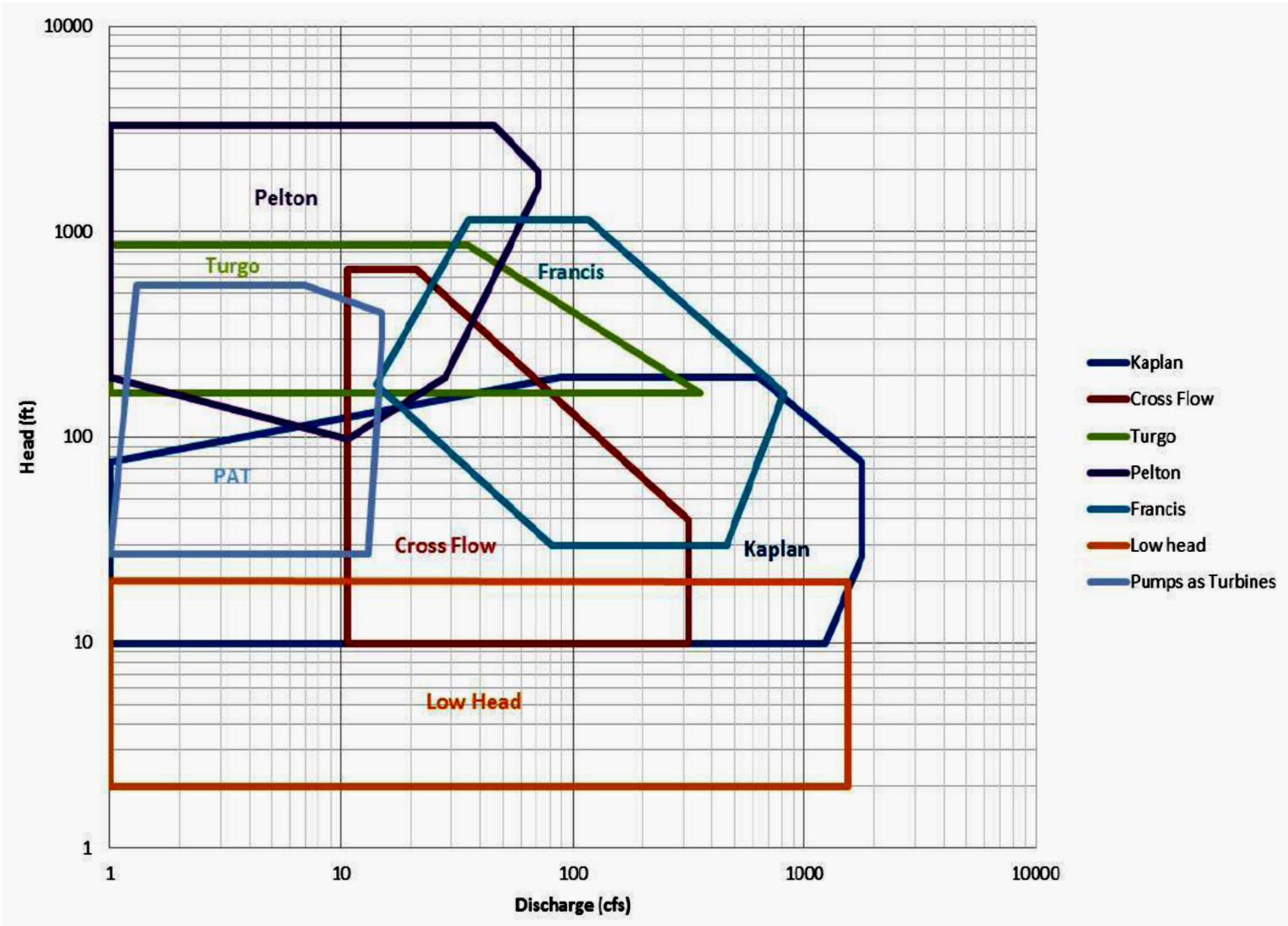
$Q = Cb\sqrt{2g}H^{3/2}$ $\quad M = \alpha' \rho U^2 S = \alpha' \rho Q U = \alpha' \rho \frac{Q^2}{S}$ $\quad h_{vc} = C h_{opening}$ $\quad m = \frac{h_2'}{h_2}$

$T_X(\chi) = \frac{1}{1 - F_X(\chi)}$ $\quad \bar{x} = \sum_{i=1}^{n} x_i \Big/ n$ $\quad \sigma_x = \sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2 \Big/ (n-1)}$ $\quad C_a = \frac{n\sum_{i=1}^{n} (x_i - \bar{x})^3}{(n-1)(n-2)\sigma_x^3}$

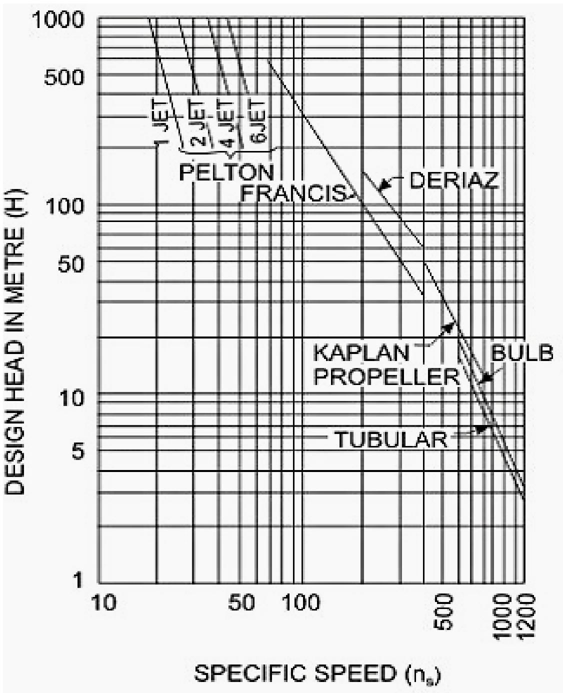
$p \cdot n = 60 f$ $\quad h_{s\max} = \frac{p_{atm}}{\gamma} - \frac{p_v}{\gamma} - \sigma H$ $\quad \sigma = 0.625\left(\frac{n_{s[\mathrm{m,kW}]}}{380.78}\right)^2$ $\quad n_s = n \frac{P^{1/2}}{H^{5/4}}$

$1\,\text{ft} \approx 0.3048\,\text{m}$

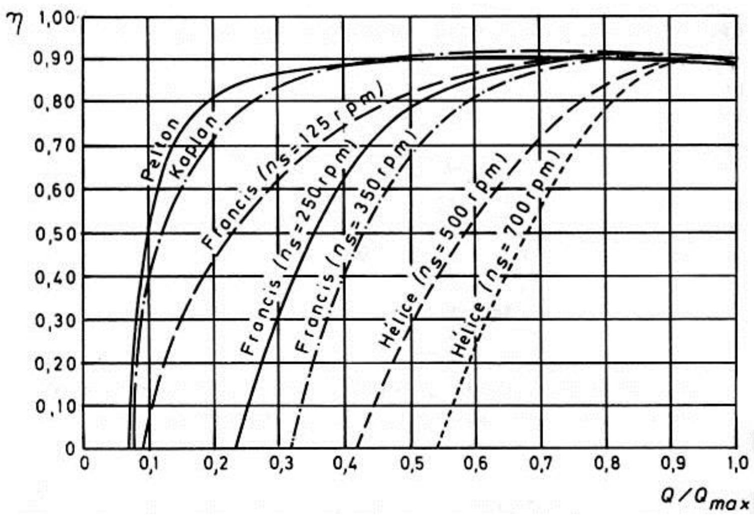
STATISTICAL LAWS	
NORMAL	$x = \bar{x} + K_N \sigma_x$ $w = \begin{cases} \sqrt{\ln\left(\frac{1}{F(x)^2}\right)} & \text{if } F(x) < 0{,}5 \\ \sqrt{\ln\left(\frac{1}{[1-F(x)]^2}\right)} & \text{if } F(x) \geq 0{,}5 \end{cases}$ $\quad K_N = \begin{cases} -\left(w - \frac{2{,}515517 + 0{,}802853w + 0{,}010328w^2}{1 + 1{,}432788w + 0{,}189269w^2 + 0{,}001308w^3}\right) & \text{if } F(x) < 0{,}5 \\ w - \frac{2{,}515517 + 0{,}802853w + 0{,}010328w^2}{1 + 1{,}432788w + 0{,}189269w^2 + 0{,}001308w^3} & \text{if } F(x) \geq 0{,}5 \end{cases}$
LOG-NORMAL (GALTON)	$x = e^{(\bar{y} + K_N \sigma_y)}$ $\quad y = \ln(x)$ $\quad y = \bar{y} + K_N \sigma_y$
GUMBEL	$x = \bar{x} + K_G \sigma_x$ $\quad K_G = -\frac{\sqrt{6}}{\pi}\left(0{,}5772 + \ln\left[\ln\left(\frac{T}{T-1}\right)\right]\right)$
PEARSON III	$x = \bar{x} + K_{III} \sigma_x$ $K_{III} = K_N + \left(K_N^2 - 1\right)\left(\frac{C_a}{6}\right) + \frac{1}{3}\left(K_N^3 - 6K_N\right)\left(\frac{C_a}{6}\right)^2 - \left(K_N^2 - 1\right)\left(\frac{C_a}{6}\right)^3 + K_N\left(\frac{C_a}{6}\right)^4 + \frac{1}{3}\left(\frac{C_a}{6}\right)^5$



Pelton
Turgo
Francis
PAT
Cross Flow
Kaplan
Low Head
Kaplan
Cross Flow
Turgo
Pelton
Francis
Low head
Pumps as Turbines
Head (ft)
Discharge (cfs)



1 JET
2 JET
4 JET
6 JET
PELTON
FRANCIS
DERIAZ
KAPLAN
PROPELLER
BULB
TUBULAR
DESIGN HEAD IN METRE (H)
SPECIFIC SPEED (n_s)



η
Pelton
Kaplan
Francis (ns=125 rpm)
Francis (ns=250 rpm)
Francis (ns=350 rpm)
Hélice (ns=500 rpm)
Hélice (ns=700 rpm)
Q/Qmax