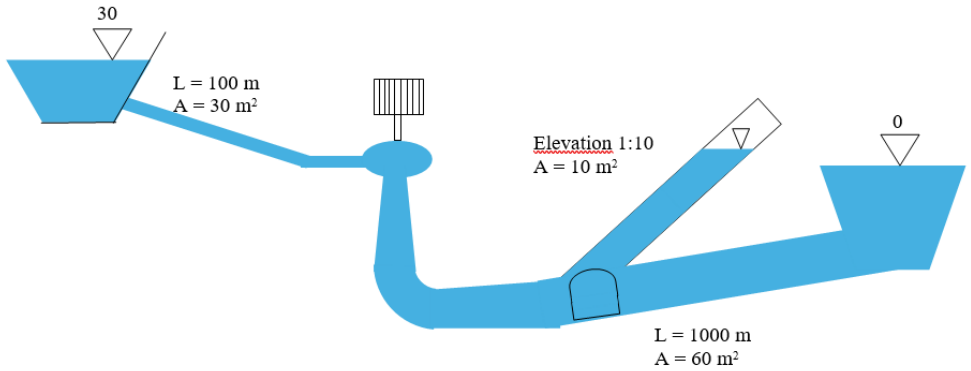
Solution Exam 2026

Problem 1

Gross Head	30	m
Q	60	m3
Head loss	0.0015Q2	
M2	38	
L1	100	m
A1	30	m2
L2	1000	m
A2	60	m2
Gradient	0,1	
A_access	10	m2
L_access	100,498756	m
As	100	m2
Head loss	5,4	m
Effective head	24,6	m
Efficiency	0,82	
Ta	7	s
Tw	3,5	s
Ta/Tw	2,0	<6
Governor Stable?	NO	
Athoma	448,0	>100
U-tube stable?	NO	
Upsurge	9,9	m
omega	0,061	rad/s
T	103,7	s

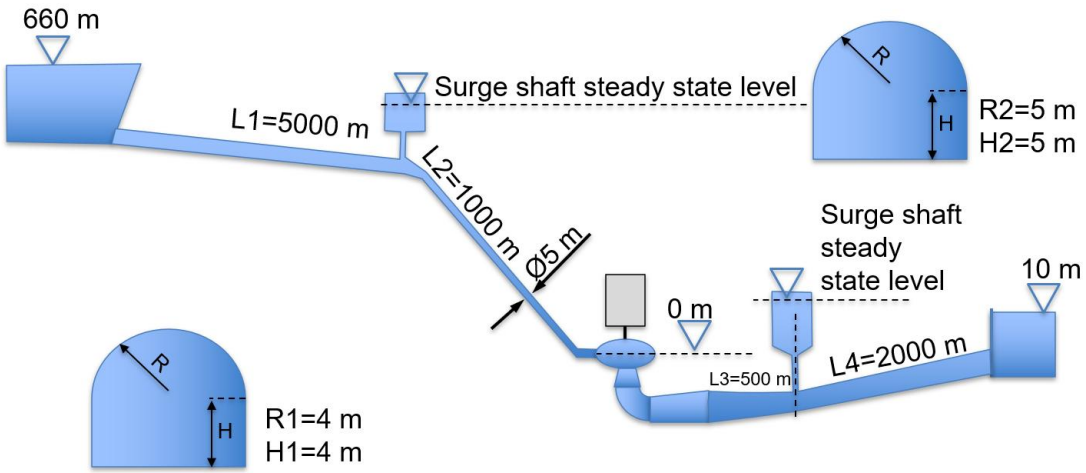


Problem 2. Head Loss

Input data:				
	Gross Head	H_G	m	650
	Flow rate	Q	m^3/s	150
	Gravity contstant	g	m/s^2	9,81
	Length of the upper tunnel	L	m	5 000
	Radius of the tunnel	R	m	4
	Height of the tunnel	H	m	4
	Length of the penstock	L	m	1 000
	Diameter of the penstock	D	m	5,0
	Length of tailrace tunnel (upto surge shaft)	L	m	500,0
	Length of Tailrace tunnel(after surge shaft)	L	m	2 000,0
	Height of tailrace tunnel	H	m	5,0
	Radius of tailrace tunnel	R	m	5,0
	Turbine efficiency	η_T		0,94
	Generator efficiency	η_G		0,98
	Transformer Efficiency	η_{Tr}		0,99
	Mannings number for all tunnels	M	$m^{1/3}/s$	34
	Friction factor for penstock	λ		0,0120

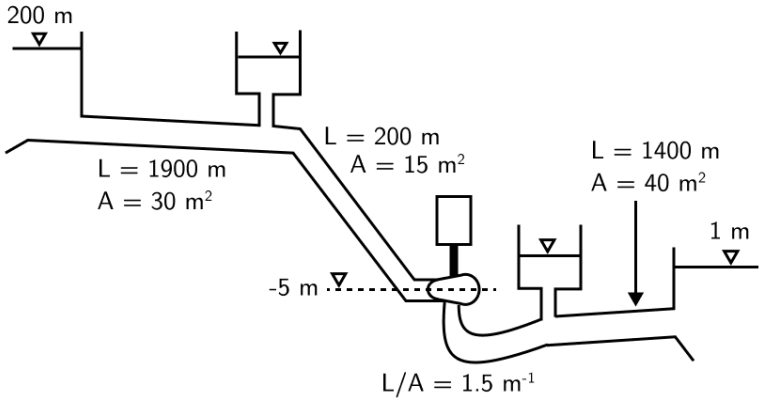
Calculated data:				
	Turbine power output	P_T	MW	870,4
	Generator power output	P_G	MW	852,9
	Transformer power output	P_{Tr}	MW	844,4
	Area of the tunnel	A1	m^2	57,1
	Area of the penstock	A2	m^2	19,6

Area of tailrace tunnel	A3	m^2	89,3
Velocity in the tunnel	C	m/s	2,63
Velocity in the penstock	C	m/s	7,64
Velocity in the tailrace tunnel	C	m/s	1,68
Perimeter of the tunnel	P	m	28,6
Hydraulic radius of headrace tunnel	R_h	m	2,00
Perimeter of the tailrace tunnel	P	m	35,71
Hydraulic radius of tailrace tunnel	R_h	m	2,50
Head loss in the headrace tunnel	H_f	m	11,83
Head loss in the tailrace tunnel(upto surge shaft)	H_f	m	0,36
Head loss in the tailrace tunnel(after surge shaft)	H_f	m	1,44
Head loss in the penstock	H_f	m	7,1
Level in the upper surge shaft		m	648,2
Level in lower surge shaft		m	11,4
Net head	H_n	m	629,23



Problem 3

Given data			
	Upper reservoir level	200	m
	Lower reservoir level	1	m
	L1	1900	m
	A1	30	m2
	L2	200	m
	A2	15	m2
	Turbine level	-5	m
	L/A Draft tube	1,5	m-1
	L3	1400	m
	A3	40	m2
	Q	35	m3/s
	M	34	
	Tc	10	s
	Δz	12	m
	a	1200	
	Ashaft downstream	120	



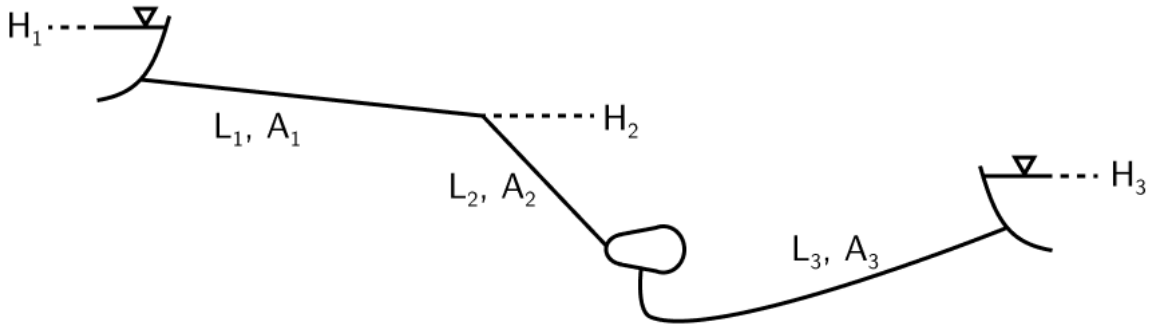
Calculated

	Ath	14,3018573	m2
	Amin	14,3018573	m2
	Ashaft for 12m upsurge	54,9208102	m2
Rigid theory	ΔH with no surge shaft	27,3530411	m
	Time of return Tr	3,5	s
Elastic theory	ΔH with no surge shaft	54,7060822	m
Elastic theory	ΔH with surge shaft	9,51410126	m
	Frequency of surge	0,04832923	hz
	Time period	130,00798	s

Problem 4

H1	400	m
L1	3500	m
A1	50	m2
H2	250	m
L2	300	m
A2	20	m2
H3	10	m
L3	1000	m
A3	50	m2
g	9,81	m/s2
Q	47	m3/s
Ta	6	

Tw	1,28989257	s	>1
Ta/Tw	4,65155015	<6	unstable



Problem 6. Francis turbine model tests

Input data:				
	Inlet pressure on the model turbine	p_{in}	kPa	235
	Differential pressure across the model turbine	Δp	kPa	160
	Atmospheric pressure	p_{atm}	kPa	93
	Flow rate on the model turbine	Q_M	m3/s	0,245
	Gravity constant	g	m/s^2	9,8
	Density of water	rho	kg/m^3	1000
	Pipe diameter at the inlet of the turbine where high pressure side of Δp is tapped	D_{inlet}	m	0,349
	Area at the outlet of the turbine where low pressure side of Δp is tapped	A_{outlet}	m/s	0,236
	Level at the inlet	Z_{in}	m	2
	Level at the outlet	Z_{out}	m	1
	Model Turbine Torque	M_T	Nm	1050
	Model Turbine Speed	n_M	rpm	350
	Prototype Turbine Speed	n_P	rpm	375
	Generator efficiency	h_G		0,99
	Model Turbine runner outlet diameter	D_M	m	0,35
	Prototype Turbine runner outlet diameter	D_P	m	1,78
	Number of runner blades	Z_{runner}		30
	Number of guide vanes	$Z_{guide\ vanes}$		28

Calculated data:

Net Head on the model turbine	H_n	m	17,3
Turbine Speed	ω	rad/s	36,7
Turbine Speed - reduced	$\underline{\omega}$		1,99
Flow rate on the model turbine - reduced	$\underline{Q_M}$		0,014
Speed number	Ω		0,24
Turbine power output	P_T	kW	38,485
Turbine efficiency	η_T		92,509 %
Flow rate on the Prototype turbine	Q_P	m^3/s	34,5291
Net Head on the prototype turbine	H_n	m	514,4486
Rotor Stator Interaction measured in the model runner	RSI	Hz	163
Rotator Stator interaction measured in the guide vanes	RSI	Hz	175

Problem 8: Head loss in RPT

Given dataa

H1	200	
H2	0	
D1	5	
D2	7,5	
L1	2000	
L2	1000	
Q	100	
Lambda	0,015	
turbine eff	0,92	
pump eff	0,89	
generator	0,96	
transformer	0,98	

flow velocity in penstock	v1	5,09295818	m/s
head loss in upstream penstock	hf1	7,93217829	m
flow velocity in tailrace penstock	v2	2,26353697	m/s
head loss in tailrace penstock	hf2	0,52228334	m
	Turbine		
Net head turbine mode	Hn	191,545538	m
	Pump		
Net head pump mode	Hn	208,454462	m
Hydraulic power turbine mode	Pth	187,906173	MW
Hydraulic power pump mode	Pph	204,493827	MW
Power supplied to grid	Pt	162,639557	MW
Power consumed	Pp	244,226557	MW