Loughborough University

Water Power

24WSP035

Semester 1 2024 In-Person Exam paper

This examination is to take place in-person at a central University venue under exam conditions. The standard length of time for this paper is **2 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam. Your invigilator will collect your exam paper when you have finished.

Help during the exam

Invigilators are not able to answer queries about the content of your exam paper. Instead, please make a note of your query in your answer script to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

Answer **ALL FOUR** questions.

All questions carry equal marks.

Use a **SEPARATE** answer book for **EACH** question.

Use of a calculator is permitted - It must comply with the University's Calculator Policy for In-Person exams, in particular that it must not be able to transmit or receive information (e.g. mobile devices and smart watches are not allowed).

A range of formulae and tables likely to be of benefit in the solution of these questions is provided at the rear of the paper.

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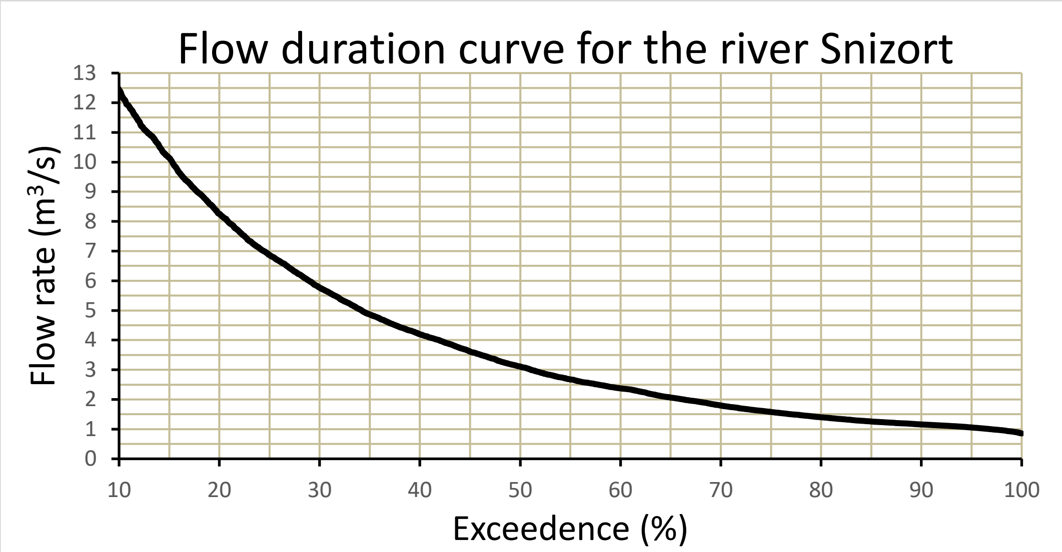
1. Water Resource



a) Explain what is meant by hydraulic head, and why its measurement at a proposed hydropower site is important. What methods might be used to measure hydraulic head? [7 marks]

b) The river Snizort on the Isle of Skye has a catchment area of 80.5 km^2 and receives an average of 6.6 mm of rain per day. Calculate the average yearly flow rate. Why might the measured flow rate be different from the value you have calculated, and how might this flow rate have been measured? [11 marks]

c) A hydropower scheme is proposed on the river Snizort. As this is an economically important salmon and trout fishing river, the local estate is concerned that the minimum flow rate should be maintained at 1.5 times the legal minimum. Using the flow duration curve given above, give the flow rate which would comply with this requirement. What is the legal minimum flow rate for this river, and what flow rate would you expect the turbine to be designed for? What are these two flow rate values referred to as? [5 marks]

d) The Snizort is an example of a “flashy” river. What does this mean, and what might it tell you about the location? [2 marks]

2. Civil Engineering

a) Most hydropower schemes either make use of a dam or use a run-of-river system. Explain the benefits of each scheme type. [6 marks]

b) What is meant by head loss, and why does it occur? What steps might be taken to minimise head loss? [8 marks]

c) Why is the use of pumped storage advantageous, and what are the potential risks and disadvantages associated with its installation and use? [6 marks]

d) Why is it important to consider geotechnical factors as well as topography when deciding on the type of scheme to implement at a prospective hydropower site? [3 marks]

e) Hydropower schemes with low hydraulic head can suffer from reduced to no output under flood conditions. Explain why. [2 marks]

3. Water Turbines

A site for potential water power exploitation has a reservoir available at a head of 200 m, filled from its catchment area at an average rate 3 m^3/s.

A penstock of length 250 m, diameter 1.2 m, and friction coefficient 0.02 has already been installed. You are considering the use of either a Pelton wheel or Francis turbine.

a) Ignoring friction and conversion efficiency losses, and considering the flow rate possible in the penstock, calculate the ***peak*** power achievable at the outlet. [3 marks]

b) Explain how specifying the Francis turbine draft tube diameter or Pelton nozzle diameter affects flow upstream in the penstock. [4 marks]

c) For a Francis turbine draft tube diameter of 0.5 m, calculate the flow rate, friction head loss, and power output (assume 80% conversion efficiency). [6 marks]

d) Compare this with a Pelton wheel with nozzle diameter 0.1 m and the same efficiency. [6 marks]

e) What practical conclusions can you draw about the operation of the two types of system and what changes could be made to optimise their suitability to the site? [6 marks]

4. Marine Power

a) Wave power has huge potential as a generation technology, but despite the significant resource, very few wave power systems have been implemented successfully, and most companies have gone bankrupt before realising a profit. Explain why this is the case. [8 marks]

b) Point absorbers are wave power devices with a particularly good capture width ratio. It has been suggested that arrays of these devices could be used to protect offshore windfarms from damage caused by large waves. How might the use of an array of point absorbers help to protect wind turbines, and what additional benefits might there be from combining wave and wind power in this way? [5 marks]

c) Considering tidal energy harvesting, describe the advantages and disadvantages of using a purpose-made artificial lagoon instead of a barrage across a natural estuary. [4 marks]

d) A circular lagoon is constructed with a diameter of 400 m, in water with a tidal range of 6 m. Calculate the maximum energy stored each tidal period. [4 marks]

e) Explain why the practical energy extractable will be lower than this theoretical maximum and one possible strategy for increasing it. [4 marks]

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Formulae you might find helpful:

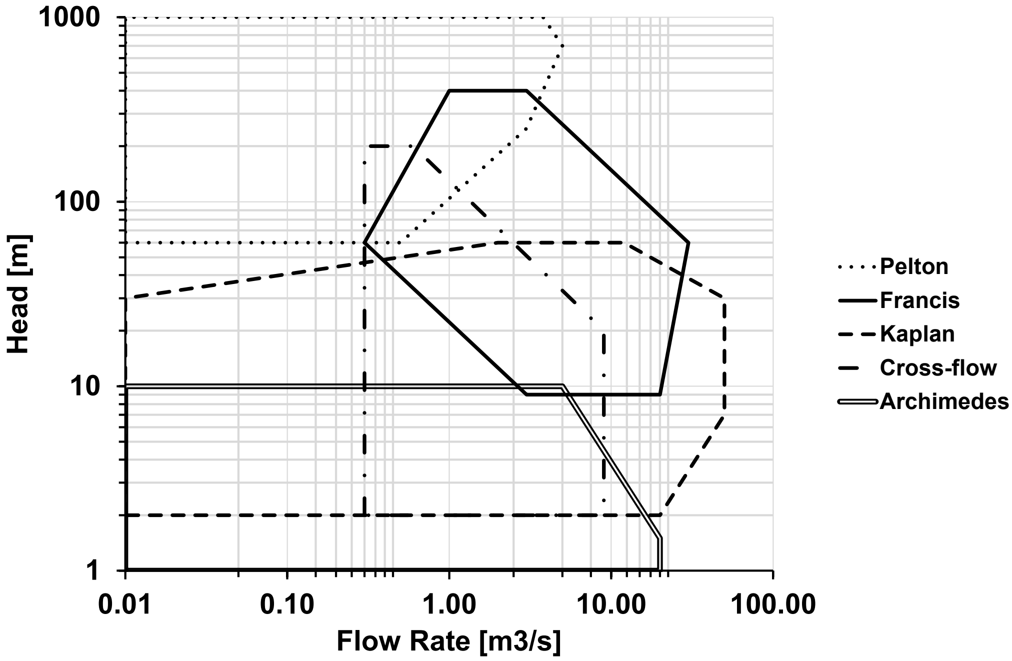
Kinetic Energy: $KE = \frac{1}{2}mv^2$

Gravitational Potential Energy: $PE = mgh$

Angular velocity [rad/s]: $\omega = \frac{v}{r}, \left(1\ rpm = {}^{2\pi}/_{60}\ rad/s\right)$

Torque from momentum change: $\tau = 2\rho r Q(v - u)$

Flow rate through a closed system: $Q = Av$



Power output of a hydropower scheme: $P = \eta \rho g Q H$

Penstock pipe friction head loss: $h_f = \lambda \frac{Lv^2}{2gD}$

where: L = pipe length in metres, D = pipe diameter, λ = pipe friction coefficient

Turbulence head loss: $h_t = \frac{Kv^2}{2g}$ *where: K = turbulence constant*

Turbine specific speed: $N_s = n\sqrt{\frac{P}{H^{5/2}}}$ *where: P is in **kW**, n is in rpm and H is in m*

General wave velocity: $v = \frac{\lambda}{T}$

Shallow water wave velocity: $v = \sqrt{gD}$

Acceleration due to gravity: 9.81 m/s^2, Freshwater density: 1000 kg/m^3, Seawater density 1025 kg/m^3