Loughborough University

WATER POWER

22WSP035

Semester 1 2022 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.

You may use a calculator for this exam. 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).

Loughborough University

WATER POWER

(22WSP035)

January 2023 2 Hours

Answer **ALL FOUR** questions.

All questions carry equal marks.

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

Any University-approved calculator is permitted.

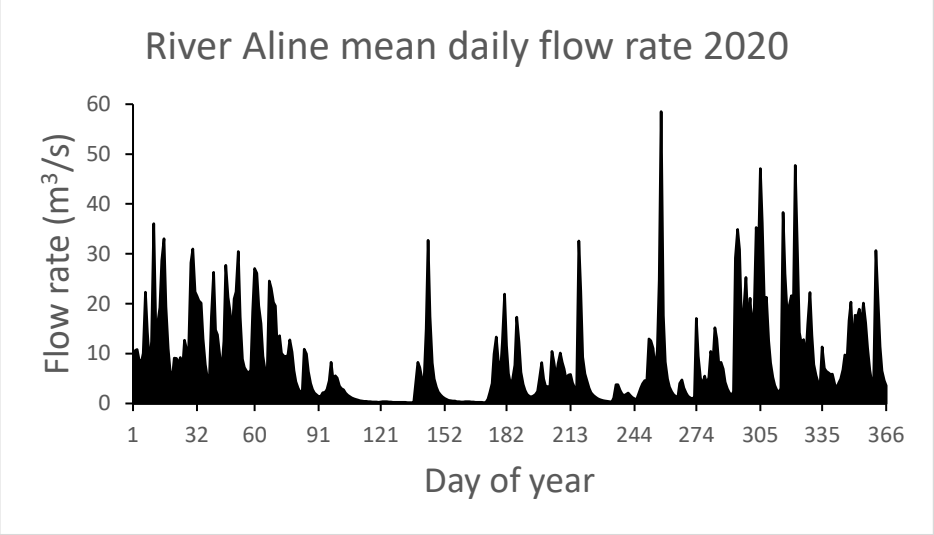
A range of formulae and tables likely to be of benefit in the solution of these questions is provided at the rear of the paper.

1.

a) What two methods are commonly used for accurately measuring the head at a prospective hydropower site? Give an advantage and a disadvantage of each. How might the head be estimated initially for a large site with a very high head? [7 marks]

b) What is a flow duration curve, and what information about a given river might you expect to be able to extract from one? [4 marks]

c) The graph below shows the mean daily flow rate of the River Aline (Morvern, NW Scotland) in 2020. What can you infer about this river and its location using this graph? [6 marks]



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d) Briefly describe the methods by which the flow rate of a river can be determined if a measurement weir is not available and a temporary weir cannot be used. [8 marks]

2.

a) Describe the differences between dammed hydropower schemes and run-of-river schemes. [8 marks]

b) Describe the following and explain their purpose: intake; silt basin; trash rack; spillway; and fish ladder or pass. [10 marks]

c) If a 200m long penstock has a pipe friction factor of 0.025, a diameter of 1.3m and a water velocity of 4m/s, calculate the head loss due to pipe friction. What is the flow rate? [4 marks]

d) Pumped storage hydropower schemes almost always include a surge shaft or surge chamber. What is the purpose of this feature, and why is it important? [3 marks]

3.

a) A 120 MW Pelton wheel with 8 jets operates with a head of 640 m and rotational speed of 400 rpm.

Calculate the water flow rate per nozzle, water jet velocity, water nozzle diameter, and specific speed. Assume there are no losses, and the system has an efficiency of 100 %. [6 marks]

b) Show that the peak efficiency of a Pelton wheel is reached when the bucket speed is half the water speed and calculate the diameter of wheel needed to achieve this for the case above. [6 marks]

c) Now considering real losses: The actual jet velocity measured on the above system is 99.8 m/s. Calculate the head loss due to friction in the penstock. [3 marks]

d) The turbine is expected to run an electrical generator producing 120 MW. The generator efficiency is fixed at 93 % and the best turbine efficiency is 78 %. Calculate the water flow needed to produce 120 MW from the generator. [5 marks]

e) Describe the main differences between impulse and reaction water power systems and explain why a Pelton wheel has been chosen in this case. [5 marks]

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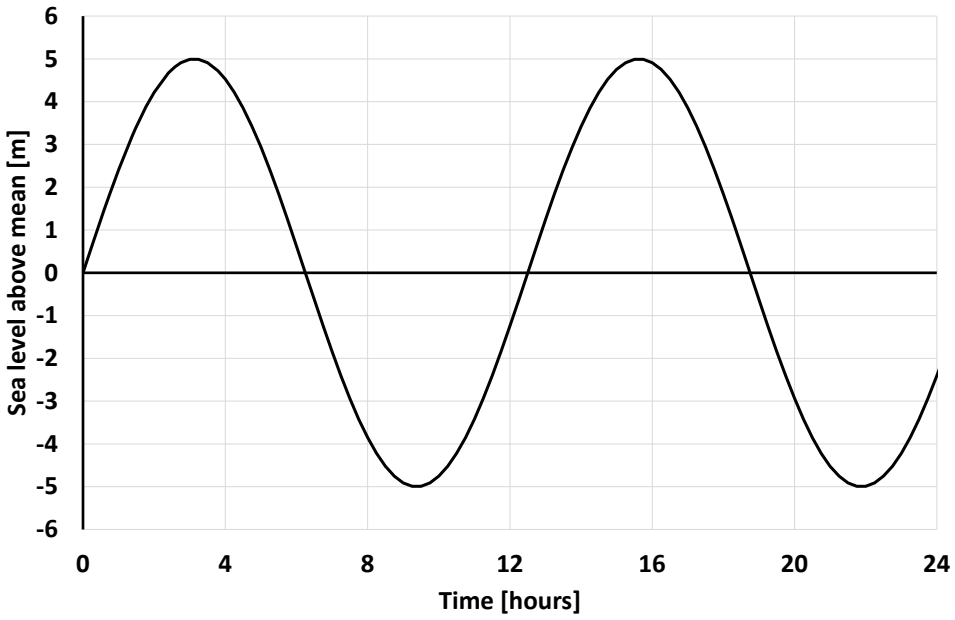
4.

a) Point absorber, surface attenuator, oscillating water column and overtopping structure are four different classes of wave energy conversion device. Give a brief description of the process by which each of these device types extracts energy from waves. [12 marks]

b) The figure below shows the variation in sea height at a location being considered for a tidal barrage power plant:



Make your own sketch and add a curve showing the basin level under ebb-only generation. Indicate what action is being taken at the different time points in the system operation. [5 marks]

c) Make a similar sketch for a two-way generation system (again indicate what action is being taken at different times in the cycle). [5 marks]

d) Explain the possible advantages of adding active pumping to such tidal barrage schemes. [3 marks

P. J. M. Isherwood
T. R. Betts

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Formulæ you might find helpful:

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

Gravitational Potential Energy $PE = mgh$

Power output of a hydropower scheme: $P = \eta\rho gQH$

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

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.*

$$Q = \left(\frac{\pi D^2}{4}\right)v$$