Loughborough University

WATER POWER

21WSP035

January 2022 (1b) Exam paper

This is a (1b) online examination, meaning you have a total of **2 hours plus an additional 30 minutes** to complete and submit this paper. The additional 30 minutes are for downloading the paper and uploading your answers when you have finished. If you have extra time or rest breaks as part of a Reasonable Adjustment, you will have further additional time as indicated on your exam timetable.

It is your responsibility to submit your work by the deadline for this examination. You must make sure you leave yourself enough time to do so.

It is also your responsibility to check that you have submitted the correct file.

Exam Help

If you are experiencing difficulties in accessing or uploading files during the exam period you should contact the exam helpdesk. For urgent queries please call **01509 222900**.
For other queries email examhelp@lboro.ac.uk

You may handwrite and/or word process your answers, as you see fit.

You may use any calculator (not just those on the University's approved list).

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WATER POWER

(21WSP035)

January 2022 2 Hours

Answer **ALL THREE** questions.

All questions carry equal marks.

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1. Morecambe Bay is a very large inter-tidal bay, which represents about 12% of the UK's entire inter-tidal area. For the purposes of this question, you are asked to address the technical issues only, and not to consider environmental or other matters.

a) The tidal chart in Figure 1.1 gives the water heights at Morecambe for one week.

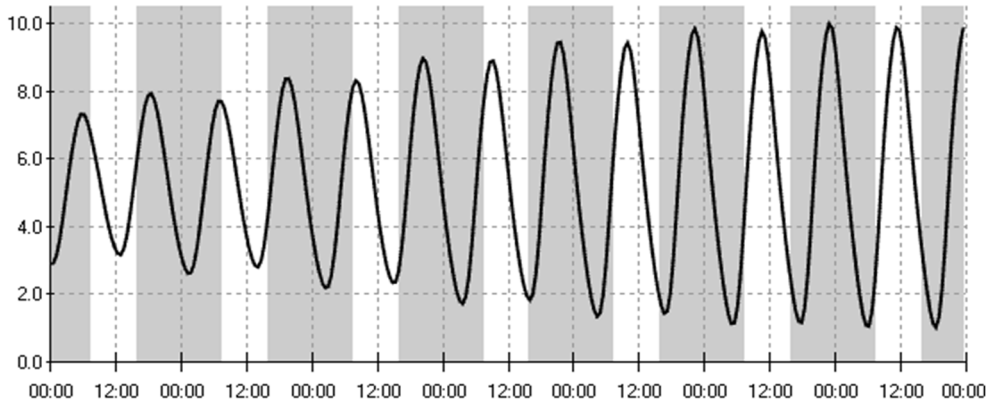


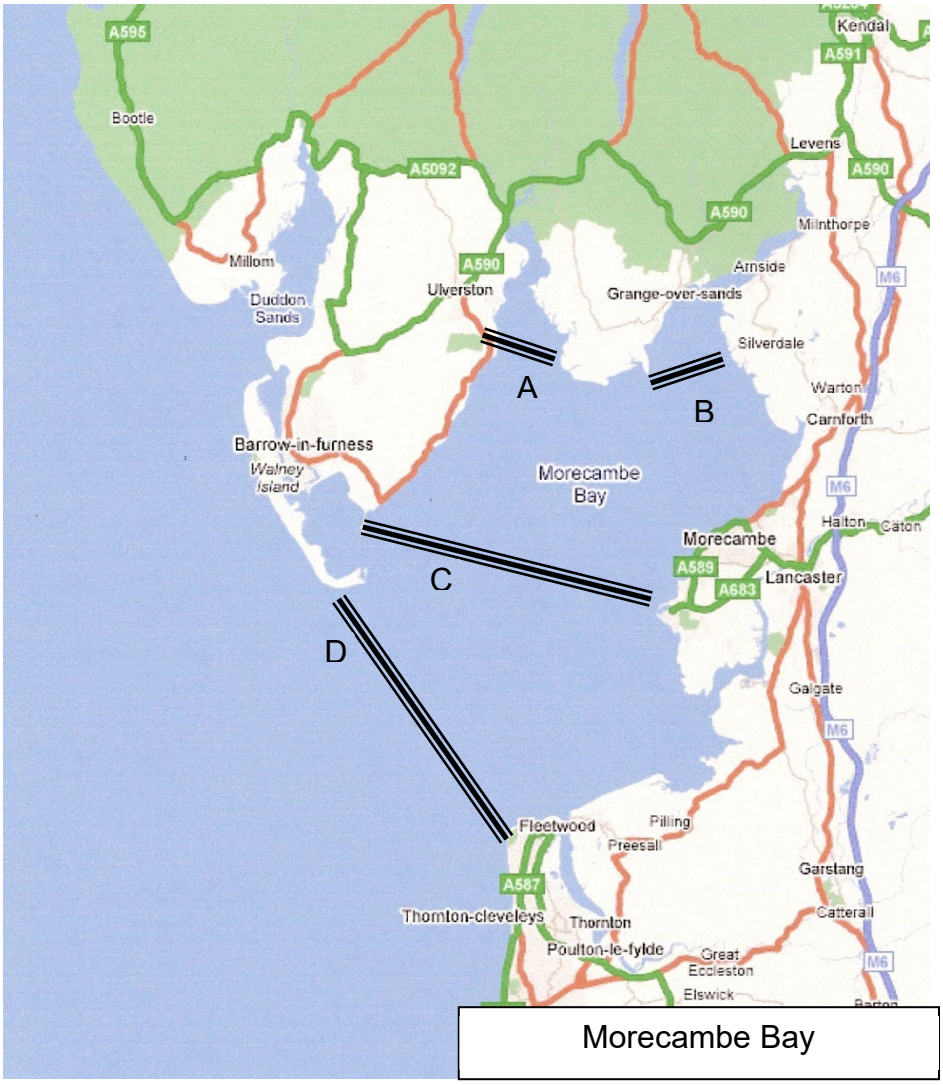
Figure 1.1: Tidal chart for Morecambe Bay

Carefully explain

i. the three mechanisms that enhance tidal ranges, and [6 Marks]

ii. why the tidal range varies over a period of several days. [2 Marks]

b) Figure 1.2 shows Morecambe Bay with four potential locations for the construction of a tidal barrage: A, B, C, and D.



	A	B	C	D
Length L [m]	4000	5000	17500	17500
Height H [m]	8	8	10	12
Area A [km^2]	20	16	306	553
Range R [m]	7.5	7.5	7.0	6.0

Figure 1.2: Map of Morecambe Bay and site parameters

i. Sketch on a single tidal cycle how you would operate a tidal barrage in "ebb" generation mode. [4 marks]

ii. Calculate the energy value of each site and use Baker's equation to evaluate the cost of energy, U, at each site.

Baker's equation: $\log U = k \log\left(\frac{L^{0.8}(H+2)^2}{A(R-1)^2}\right)$, where k = 0.3 [4 marks]

iii. Which site(s) would you develop and why? Comment on the results, and consider the possibility of utilising both A and B. [4 marks]

/continued

2.

a) A 1/8 scale Francis turbine model is tested under a head of 50 m. The full-scale turbine is required to run at 500 rpm. You may assume that all the losses are zero.

i. If the full-scale turbine develops 324 MW and uses 66 m^3 of water per second at this speed, what power would be obtained from the model scale turbine? [4 marks]

ii. At what speed must the model be run? [2 marks]

iii. What are the specific speeds of the model–scale and full-scale turbines? [2 marks]

b) This Francis arrangement is the design of the turbines installed at the Dinorwig pumped storage power station in Wales. Here six such Francis turbines operate as hydroelectric generators under the head and flow conditions outlined above, but with an efficiency of 92.5%. When there is a demand on the grid, each of the turbines can be run up to their full output of 325MW in 10 seconds.

These turbines can be run in reverse to each pump water at a flow of 50 m^3/s. When pumping starts, all six turbines are employed to pump water into the upper reservoir for 1.5 hours.

i. If the surface area of the reservoir is 200,000 m^2, is initially 500 m above the turbines, and the efficiency of the turbines as pumps is 91.7%, calculate the rise of the water level in the reservoir. [2 marks]

ii. What is the energy stored by this action? [2 marks]

iii. How much energy is lost in the pump/generate cycle due to the turbine efficiency? [5 marks]

iv. Why would you choose a Francis turbine for this role rather than a Pelton Wheel? [3 marks]

3.

a) Describe the operation of shore mounted Oscillating Water Column (OWC) wave energy converters. Include a sketch and give particular emphasis to the characteristics of the Wells turbine. [4 marks]

b) Estimate the physical dimensions of an OWC that you would build at a deep water location to extract energy from waves with an energy period of 8 seconds and power level of 20 kW/m. [2 marks]

c) A Wells turbine is fitted to the OWC described above. It has a tip diameter of 1.0 m (hub diameter can be neglected) and a damping rate of 650 Pa s/m^3 (ratio of pressure drop to air flow) when coupled to an induction generator at a synchronous speed of 3000 rpm. Incident waves produce a pressure drop across it of 12 kPa.

i. Calculate the air flow rate, the mean air velocity, the tip speed, and the total air expelled in 5 seconds. [4 marks]

ii. The last value indicates the volume of the air chamber. How would the OWC respond when subjected to much larger waves? State your reasoning and comment on the results. [2 marks]

d) Figure 3.1 below illustrates a wave farm which consists of 3 rows of 6 point absorbers. Each point absorber has a diameter (D) of 6 m. The spacing between absorbers (S) is 94 m, and the distance between successive rows (R) is 250 m.

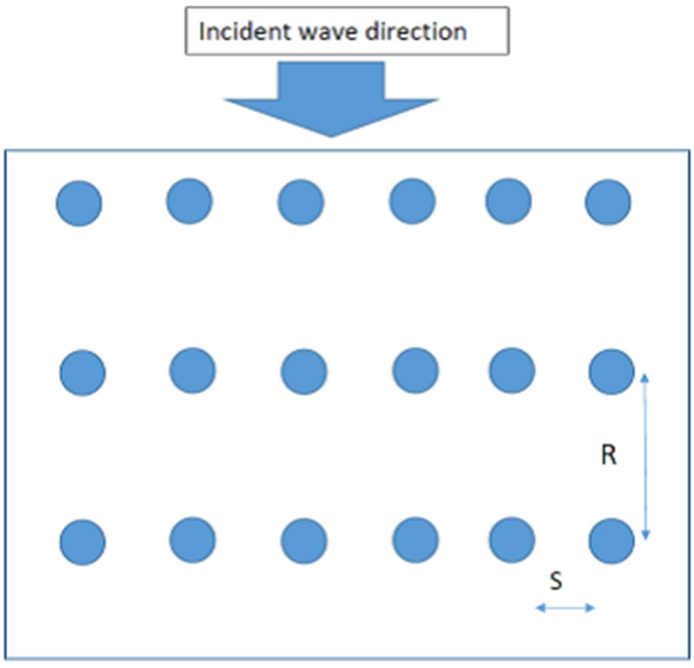


Figure 3.1: Wave farm consisting of 3 rows of 6 point absorbers

If the Capture Width Ratio (CWR) of the point absorbers is 3.5, calculate the power captured by the 6 point absorbers in row 1, row 2 and row 3 from an incident wave power of 60 kW/m. Assume that the point absorbers do not reflect any wave power. Comment on the result and describe the response if the wave direction changes by up to +/- 90 degrees. [8 marks]

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