10.6 A wind turbine has rotor diameter of 90 m. It is installed on monopile with a diameter of 4 m in diameter in water 15 m deep. The wind speed is 12 m/s, the wave height is 2 m and the wave length is 100 m. Estimate the force due to the wind and the maximum force due to waves. Use the Airy model for the waves and assume that the rotor thrust coefficient is the one corresponding to the Betz power coefficient. Assume that inertia coefficient is 2.0 and the drag coefficient 1.5. (Assume that the maximum forces due to drag and inertia occur at the same time.)

The rotor force, $F_R$, is:

$$F_R = 0.5 C_T \rho \pi \frac{D^2}{4} U^2$$

The maximum inertial wave force with wavelength $L = 100$ m is:

$$F_I = \rho_w g \left( \frac{C_m \pi D^2}{4} \right) \frac{\zeta}{\tanh(\zeta d)}$$

The maximum wave force due to drag is:

$$F_D = \rho_w g \frac{C_d D}{2} \frac{\zeta}{2} \left[ \frac{1}{2} + \frac{kd}{\sinh(2kd)} \right]$$

$$= \text{kN}$$
A small community has 2000 residents and each of them consumes an average of 100 liters of water per day. They have access to an aquifer 100 m below ground level and are considering acquiring a wind electric water pump to bring the water to the surface. What would be the rated power of wind turbine (kW) that would pump, on the average, an amount of water equal to what the community uses? Assume that the capacity factor of the wind turbine is 0.25 and that the efficiency of the water pump is 80%.

Assuming 2000 people, consuming 100 liters/day person (0.1 m³/day person), the total community water requirement is 200 m³/day.
Assuming a water density of 1000 kg/m³, the average mass flow rate is:

\[ \dot{m} = \text{kg/s} \]

The power requirement is

\[ P_{\text{water}} = \dot{m} \cdot \text{gh} / \eta = \text{W} \]

The rated power of the turbine would be:

\[ P_R = P_{\text{water}} / \text{cap.fact.} = \text{kW} \]
10.8  An island community has 2000 residents and each of them consumes an average of 100 liters of water per day. The community is considering acquiring a wind powered desalination plant to produce pure water from sea water (density = 1020 kg/m³). The sea water is 20° C and has salinity of 38 g/kg. What size wind turbine would produce, on the average, an amount of fresh water equal to what the community uses? Assume that the capacity factor of the wind turbine is 0.25, and that the desalination plant uses 5 times the minimum theoretical amount of power.

Since 20° C = 293° K, the osmotic pressure is:

\[ p = iS \rho_n R_n T / M \]

\[ = \text{KPa} \]

The minimum amount of power required is

\[ P_{\text{min}} = p / 3600 = \text{kWh/m}^3 \]

(Note that 1 kPa = 1 kN/m³ = 1 kJ/m³ = 1 kW/s/m³ = (1/3600) kWh/m³.)

Assuming 4 times theoretical, the power consumption is 4.04 kWh/m³.

Assuming 2000 people, consuming 0.1 m³/day person, the total community water requirement is 200 m³/day. The average power requirement is then 807 kWh/day or 33.6 kW.

The wind turbine rated power would be \( P_r = P_{av} / \text{cap fac} = 33.6 / 0.25 = 134.5 \text{ kW} \). It may be noted that the required turbine power required to desalinate water is considerably greater than that required to pump the equivalent amount of water in Problem 10.7.
10.13 The famous dirigible Hindenburg had a volume of approximately 199,000 m\(^3\). It was filled with hydrogen to give it buoyancy. Assume that the pressure inside was 100 kPa and that the temperature was 15° C. How much hydrogen did the Hindenburg contain? How much energy (kWh) would it take to produce that hydrogen by electrolysis of water, assuming an electrolyzer efficiency of 65%? How long would it take to produce that hydrogen using a 1.5 MW turbine, operating at full power?

Use the ideal gas law to find the mass of hydrogen. First convert the temperature, 15° C to 288° Kelvin.

\[
m = \frac{PVM}{R_uT} = \text{kg}
\]

The energy, \(E\), required to produce that amount of hydrogen would be:

\[
E = \text{kWh}
\]

The time, \(t\), that the turbine would need to run at full output would be:

\[
t = 677 \text{ hr}
\]