1. Resistance and Propulsion

1-A)

The still water resistance of a model of a supply vessel has been measured in a towing tank for a range of model speeds.

Question:

Show the principle of the extrapolation of these model scale data to full scale.

See the Syllabus section 4.7 The towing tank measurements are reduced to dimensionless coefficients Ctm for the total resistance at each model speed. The model speeds are scaled to full size speeds by means of the Froude law. Ctm is split in Cfm and Crm (frictional resistance coefficient and residual resistance coefficient). For full scale and model scale the value of Cf can be based on the ITTC curve. Froudes assumption was that Cr is identical in model scale and full scale. A refinement is using the form factor method to split Cr in a wave resistance coefficient and a form resistance coefficient : see equation 4.45 of the syllabus. You may illustrate this process by a graph like fig 4.10 in the syllabus.

1-B)

This supply vessel has been equipped with one fixed pitch propeller.
Available or known quantities of the ship are:

- loading condition with wetted hull surface area S
- density ρ of the surrounding sea water
- diameter of propeller D
- open water propulsion characteristics of the propeller (K_T and K_Q versus J)
- relative rotative efficiency η_r (constant value)
- thrust deduction fraction t (constant value)
- mechanical efficiency η_m of the shaft bearings behind the power measuring device in the engine room (constant value)

Onboard of this ship - when sailing at sea with a constant engine setting in deep and very calm water - will be measured:

- time averaged value of ship speed V_{kn} in knots (1 kn = 0.5144 m/s)
- time averaged value of propeller rate N (rpm)
- time averaged value of power P_{ER} at the propeller shaft in the engine room (kW)

Effects of wind, sea state, fouling, maneuvering, etc. on the performance of the ship may be neglected. Ship speed, propeller rate and shaft power measuring devices have been calibrated a few days ago.

Question:

Describe - under these pre-defined conditions - the principle of the determination of the full-scale wake fraction w of this vessel from the requirement that:

Calculated Torque = Measured Torque.

What you need to determine is the hull efficiency, see equation 4.82 in the syllabus. Since η_r is known and the open water efficiency can be derived from Kt and Kq, you can base the calculation on the overall efficiency (eq. 4.79 – 4.80) which follows from the resistance prediction of the modeltest and the measured torque. Remember that the torque at the propeller is the measured torque x η_{m}.

2. Regular and Irregular Waves

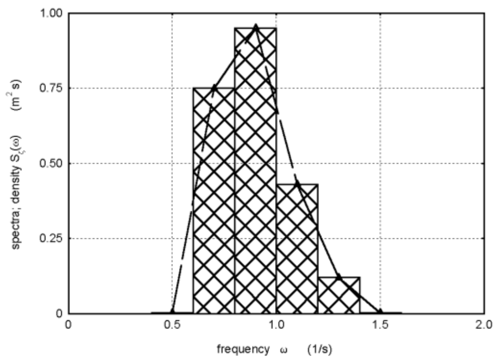
2-A)
A towing tank has a length of 150.00 m, a width of 5.00 m and a wave maker in one end that generates long-crested regular waves.
Assume in this tank a generated regular deep-water wave with amplitude $\zeta_a = 0.200\,\text{m}$ and wave period $T = 2.00\,\text{s}$.
The velocity potential of the wave is given by:

$$\Phi_w = \frac{\zeta_a \cdot g}{\omega} \cdot e^{k \cdot z} \cdot \sin(k \cdot x - \omega \cdot t) \qquad \text{with: } \rho = 1000 \text{ kg/m}^3 \text{ and } g = 9.81 \text{ m/s}^2.$$

Questions:

- Determine for this regular wave: the circular wave frequency ω, the wave number k, the wavelength λ and the energy in these waves per unit surface area E/A.
  Deep water wave, so ω^2 =kg and of course ω = $2\pi/T$ = 3.14 so k =1.006
- Determine the phase velocity c, the group velocity c_g of these waves and the time needed by this wave train to reach the other end of the tank.
  See syllabus equation 5.4 and 5.86-5.87
- Determine the maximum fluid particle velocities (in longitudinal and vertical direction) in the fluid in the tank at 0.500 meter below the still water level.
  See syllabus equation 5.56
- Determine also the maximum pressure at 0.500 meter below the still water level.
  See syllabus equation 5.66-5.67

2-B)
A simplified wave energy spectrum of a storm in the North Atlantic Ocean, measured by a disposable wave buoy, is given by:



ω (s^{-1})	0.5	0.7	0.9	1.1	1.3	1.5
$S_\zeta(\omega)$ ($m^2 s$)	0.00	0.75	0.95	0.43	0.12	0.00

Sketch and definition of a wave spectrum

Questions:

- Calculate the significant wave height, $H_{1/3}$, and the mean wave periods T_1 and T_2.
  Spectral area m0 = 0.45 m2 so $H_{1/3}$ = 2.68 m T1= 7.04 s T2= 7.0

- Determine the probability P of exceeding a wave height of 4.00 meter in this storm, by using the Rayleigh probability density function.
  1.2%   See syllabus eq 5.103
- Determine also the number of times per hour that this wave height will be exceeded.
  *Number of waves is 3600/7 =514 so 0.012*514 = 6 times*
- What is the probability that the significant wave height $H_{1/3}$ will be exceeded?
  6.8%

Note that this exam appears to be incomplete, you would get basic formulae with it.