# Final Exam

**Dec. 10, 2013**
**1:00~3:00 PM**

1. (20%) Derive the dynamic and kinematic nonlinear free-surface boundary conditions of gravity waves. Derive the linearized free-surface boundary conditions, and then combine kinematic and dynamic conditions to make one equation.

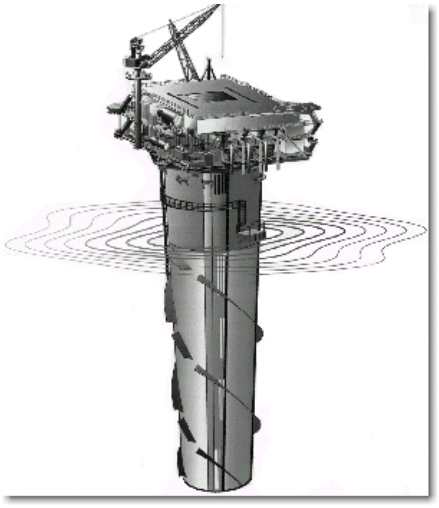
2. (25%) In a certain location of ocean, you installed a velocity and pressure sensors at 20m depth. Once you measured a regular oscillatory signal of horizontal velocity with the period of 10sec and amplitude 3m/sec. Assuming linear waves in deep water, answer the following questions:

(1) (5%) What are wavelength and wave amplitude?
(2) (5%) What are the phase and group velocities of the waves?
(3) (5%) What is the amplitude of vertical velocity?
(4) (5%) Estimate the maximum pressure.
(5) (5%) What is the mean wave energy density in a unit width if the waves are plane progressive?

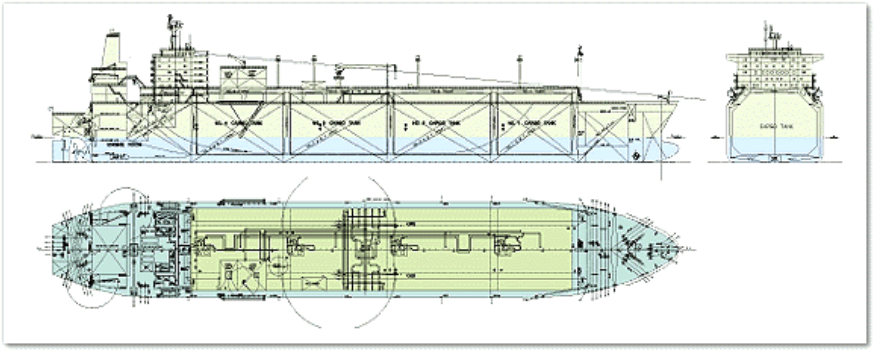
3. (35%) You are going to design a spar platform of 20m diameter and 150m draft. In a long period of observation, people found that ocean environment at the installation location can be summarized into the following table of wave height.

| Wave height | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total |
|---|---|---|---|---|---|---|---|---|---|
| No. of observation | 1500 | 3000 | 5500 | 2100 | 1400 | 900 | 500 | 100 | 15000 |

(1) (5%) What the significant wave height of this ocean? What is the 1/10 highest wave amplitude?
(2) (10%) You want to find the design wave height of return period of 100 years. By using the significant wave height obtained above, compute the wave height of 100-year return period. The mean wave period of this region is 8 sec.
(If you cannot solve Prob. (1), assume a certain value for the significant wave height.)
(3) (15%) Assuming that the period of the design wave is 12sec, find the maximum inertia and drag forces on this spar.
(4) (5%) If the averaged velocity in this sea area is 2 m/sec, estimate roughly the period of vortex-induced vibration.



4. (20%) Sloshing analysis in membrane-type LNG cargo is one of the key technologies in LNG cargo design for LNG carriers, LNGC, LNG-FPSO, and LNG-FSRU. Violent sloshing flow can occur when the ship motion frequency is resonant with the fundamental standing model of sloshing flow. Therefore, the ship designers want to avoid the sloshing resonance with ship motion. Your task is to observe sloshing resonance for a ship designed by SHI.



(LNG carrier designed by Samsung Heavy Industry)

This ship is about 278m length and 42.6m wide. If one LNG cargo is 37m wide and 35m high, answer the followings, assuming the cargo is rectangular:

(1) (7%) Write the natural frequencies of fundamental (i.e. 1$^{st}$ mode) and 2$^{nd}$ mode sloshing mode in sway/roll direction at 50% filling.
(2) (5%) Briefly sketch the linear movement of free surface and particles inside the tank when the fundamental and 2$^{nd}$ mode waves occur.
(3) (8%) If this ship experiences regular roll motion with 10 sec period, is there any filling depth which should be avoided in (in the aspect of sloshing resonance with roll motion)?

## Good Luck!!