CONFIDENTIAL

UNIVERSITI KUALA LUMPUR
MALAYSIAN INSTITUTE OF MARINE ENGINEERING TECHNOLOGY

FINAL EXAMINATION
JANUARY 2016 SEMESTER

COURSE CODE	:	LNB 31203
COURSE NAME	:	SEAKEEPING & MANEUVERING
PROGRAMME NAME	:	BACHELOR OF NAVAL ARCHITECTURE AND SHIPBUILDING (HONS.)
DATE	:	25 MAY 2016
TIME	:	09.00 AM – 12.00 PM
DURATION	:	3 HOURS

INSTRUCTIONS TO CANDIDATES

1. Please CAREFULLY read the instructions given in the question paper.
2. This question paper has information printed on both sides of the paper.
3. This question paper consists of only ONE (1) section. Answer only FOUR (4) questions.
4. Please write your answers on the answer booklet provided.
5. Answer all questions in English language ONLY.

THERE ARE 8 PAGES OF QUESTIONS, INCLUDING THIS PAGE.

INSTRUCTION: Answer only FOUR questions.
Please use the answer booklet provided.

Question 1

(a) For a travelling wave, the surface elevation $\xi = a \sin kx - \omega t$ and the dispersion relation is $\omega^2 = gk \tanh kd$. By using the information, derive the wave celerity in shallow water to be $c = \sqrt{g.d}$

(5 marks)

(b) Ships or marine vehicles are built mainly for transportation and any special function. To accomplish its mission it must be able to float upright with sufficient stability, travel at intended speed, manoeuvre safely and satisfactory motions or seakeeping. Waves not only affect ship motions (heave, pitch, roll and etc) but also its dynamic effects and performance. Therefore, briefly explain the effects of waves on vessels.

(5 marks)

(c) Horizontal component of wave particle motion is given by

$$\underline{u} = \frac{\partial \phi}{\partial x} = \frac{gak}{\omega} \frac{\cosh k(z+d)}{\cosh kd} \sin(kx - \omega t)$$

Show that, in shallow water, the particle velocity is $\underline{u} = \frac{ga}{\sqrt{gd}} \sin(kx - \omega t)$. Briefly describe the effect of decreasing water depth to the particle velocity, $\underline{u}$.

(7 marks)

(d) A group of waves is 200 m in length in deep water. The waves within the group are 25m in length

i. Calculate the time taken for a component wave to travel the length of the group.

(5 marks)

ii. Calculate how far the group would have progressed during this time.

(3 marks)

Question 2

A ship has the following parameters:

$L = 145$ m

$B = 32$ m

$T = 8.5$ m

Block coefficient = water plane coefficient

Added mass = 75% of ship mass

Assuming there is no damping

Determine:

(a) Calculate the heaving period in still water

(8 marks)

(b) Derive the expression for heaving oscillation in still water if the initial displacement from the equilibrium position and the velocity of the heaving motion at the instants of time t = 0s and 1.8 m/s, respectively.

(8 marks)

(c) Calculate the maximum force exerted on the deck of the ship by a winch that weights 35kN when the ship is heaving in still water if the initial displacement from the equilibrium position and the velocity of the heaving motion at the instant of t = 0s are 0m and 1.8m/s, respectively

(9 marks)

Question 3

For a ship travelling in a seaway the following has been given:

L = 137m	C_{wp} = 0.80
B = 21.3m	V_s = 25 knots
T = 8.5 m	C_B = 0.65
ρ = 1025kg/m^3	ω_e = 1.18rad/s
ζ_a = 3.05m	k_{yy} = 32 m
GM_L = 135 m	$\mu = 30^o$

In additional:

i) Added mass moment of inertia is 55% of the mass moment of inertia of the ship

ii) Non-dimensional damping coefficient of pitching motion

$$b'_{pitching} = \frac{b\sqrt{gL}}{\Delta L^2} = 0.07$$

iii) The non-dimensional amplitude of the pitching moment,

$$f_o = \frac{M_o}{\frac{1}{2}\rho g \zeta_a L^2 B} = 0.25$$

Find:

(a) Natural frequency of pitching motion

(6 marks)

(b) Amplitude of the pitching motion

(12 marks)

(c) Phase differences between the wave and the pitching motion

(7 marks)

Question 4

(a) Explain how a wave spectrum typically changes shape as a wind of constant strength starts blowing over a previously calm ocean. Assume unlimited fetch and deep water. Use diagrams to support your question.

(5 marks)

(b) Plot the wave spectrum and find the total energy for the irregular wave that is made up of 5 regular wave components as follows:

Wave Component	1	2	3	4	5
Length (m)	385	171	96	61	43
Height (m)	1	1.6	2.4	2.2	1.4

(8 marks)

(c) The rolling double amplitudes (i.e. peak to peak) of a ship in an irregular seaway were measured. The results are presented in the table below. Find the average, significant and average of one-tenth highest rolling motions.

Double amplitude rolling angle (degrees)	Number of occurrences	Double amplitude rolling angle (degrees)	Number of occurrences
1	1	11	5
2	4	12	2
3	7	13	4
4	10	14	3
5	13	15	1
6	8	16	0
7	12	17	2
8	10	18	2
9	8	19	0
10	7	20	1

(12 marks)

Question 5

(a) When using an earth fixed axis system, the surge and sway forces and yaw moment on a ship in the horizontal plane are given by:

$$X_0 = m\ddot{x}_0 \qquad \text{(Surge)}$$
$$Y_0 = m\ddot{y}_0 \qquad \text{(Sway)}$$

Show the equations of motion in a body fixed axis with the origin at the centre of gravity are given as follows:

$$X = m(\dot{u} - v\dot{\psi})$$
$$Y = m(\dot{v} - u\dot{\psi})$$

(7 marks)

(b) Derive the formula for the steady heel angle of a ship in a turn given the outward centrifugal force in a turn can be obtained from:

Centrifugal force = mV^2/R (Newtons)

Where;

m = ship mass

R = steady turn radius

V = instantaneous linear velocity of the ship (tangential to the ship's path)

State all assumptions.

(8 marks)

(c) A conceptual ship design has the following particulars:

Length = 140m

Beam = 25m

Draught = 10m

Block Coefficient = 0.75

Longitudinal centre of gravity is at midships.

The ship is to operate in sea water (ρ = 1025 kg/m^3) .

The linear manoeuvring derivatives have been estimated using empirical formulae by Clarke (1982), as follows:

$Y_v^{'} = -0.02805$ $\qquad N_r^{'} = -0.00397$

$N_v^{'} = -0.01076$ $\qquad Y_r^{'} = 0.00492$

Additionally the rudder derivatives are as follows:

$$Y'_{\delta} = 0.00100 \qquad N'_{\delta} = -0.00050$$

The ship is travelling forward in a straight line at 12 knots with rudder midships. The rudder angle is changed to 35 degrees to port. Find the steady turn radius.

(10 marks)

Question 6

(a) List the two (2) advantages and two (2) disadvantages of captive model experiments

(4 marks)

(b) Briefly describe ONLY two (2) of the following measurements of manoeuvrability:

i) The turning circle
ii) The Kempf zig-zag
iii) The Dieudonne spiral

In each case, sketch the results you would expect.

(6 marks)

(c) List and sketch three (3) types of conventional rudder used as a kind of control devices as to maintain a steady course or to change the state of motion of a ship.

(6 marks)

(d) Calculate the force and torque on the center line gnomon rudder shown, Figure 1, for 35 degrees and a ship speed of 20 knots. The ship is fitted with twin screws.

(9 marks)

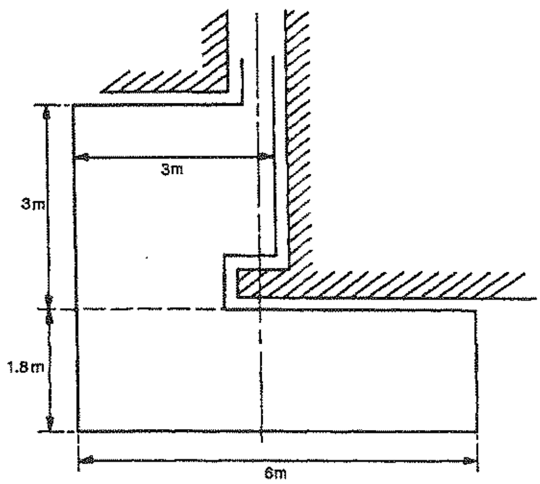


Figure 1

END OF QUESTION

FORMULA SHEET

Properties of Harmonic Waves in Deep Water

Surface profile (i.e. elevation of line of equal pressure at z = 0),

$\zeta = \zeta_a \cos(kx - \omega t)$

Wave velocity or celerity,

$V_w = \frac{L_w}{T_w} = \frac{g}{\omega_w} = \left(\frac{gT^2{}_w}{2\pi}\right)$

Wavelength, $L_w = \frac{2\pi V^2{}_w}{g} = \frac{2\pi g}{\omega_w^2} = \frac{gT_w{}^2}{2\pi}$

Wave Number,

$k = \frac{2\pi}{L_w} = \frac{\omega_w{}^2}{g} = \frac{g}{V_w^2} = \frac{4\pi^2}{gT_w^2}$

Wave Period, $T_w = \left(\frac{2\pi L_w}{g}\right)^{\frac{1}{2}}$

Energy per unit wave Surface, $E = \frac{1}{2}\rho\zeta_a^2$

Properties of Harmonic Waves in water of any depth

Elevation of lines of Equal Pressure,

$\zeta = \zeta_a \frac{\sinh k(-z+d)}{\sinh kd}\cos(kx - \omega t)$

Surface profile (i.e. elevation of line of equal pressure at z = 0),

$\zeta = \zeta_a \cos(kx - \omega t)$

Horizontal water velocity,

$u = \zeta_a V_w k \frac{\cosh k(-z+d)}{\sinh kd}\cos(kx - \omega t)$

Vertical water velocity,

$w = \zeta_a V_w k\left(\frac{\sinh k(-z+d)}{\sinh kd}\right)\sin(kx - \omega t)$

Wave Velocity or celerity,

$V_w = \left(\frac{gL_w}{2\pi}\tanh kd\right)^{\frac{1}{2}}$

Note: for shallow water ($d \langle \frac{L_w}{20}$),

$V = \sqrt{gd}$

Velocity Potential

The mathematical expression for ϕ (velocity potential) satisfying the boundary conditions :

$$\phi_d = -\frac{g.a}{\omega}.\frac{\cosh k(z+d)}{\cosh kd}.\cos(kx - \omega t)$$

Wave Relationships

$$c = \frac{\lambda}{T} = \sqrt{\frac{g}{k}\tanh \ kd}$$

$$\therefore \ \lambda = T.\sqrt{\frac{g}{k}\tanh \ kd}$$

$$= T.\sqrt{\frac{g}{2\pi}\lambda \tanh \left(\frac{2\pi d}{\lambda}\right)}$$

$$= T.\sqrt{\lambda}\sqrt{\frac{g}{2\pi}\tanh \left(\frac{2\pi d}{\lambda}\right)}$$

$$\therefore \ \sqrt{\lambda} = T.\sqrt{\frac{g}{2\pi}\tanh \left(\frac{2\pi d}{\lambda}\right)}$$

$$\therefore \ \lambda = T^2.\frac{g}{2\pi}\tanh \left(\frac{2\pi.d}{\lambda}\right)$$

Encountering Frequency

$$\omega_E = \omega_w \left(1 - \frac{\omega_W V_S}{g}\cos\mu\right)$$

Heaving Motion

For the steady condition the amplitude of the forced heaving motion z_a is given by:

$$z_a = z_{st}.\ \mu_z$$

Where, z_{st} = static heaving amplitude = $\frac{F_o}{c}$

μ_z = magnification factor = $\frac{z_a}{z_{st}}$

$$\mu_z = \frac{1}{\sqrt{(1-\Lambda^2)^2 + 4k^2\Lambda^2}}$$

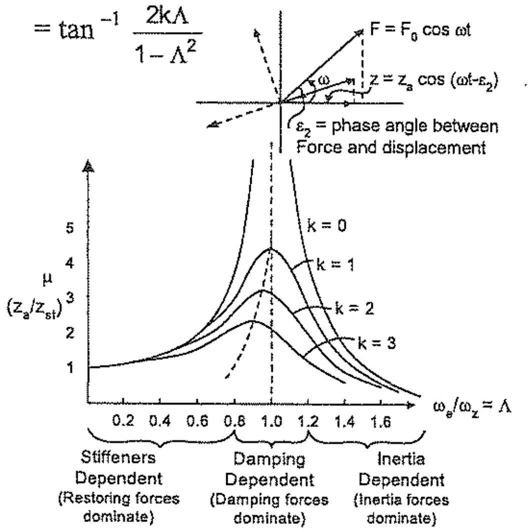
k = non-dimensional damping factor

$$= \frac{\nu}{\omega_z}$$

and $\nu = \frac{b}{2(m+a_z)}$, $\omega_z = \sqrt{\frac{c}{(m+a_z)}}$

ϵ_z = phase angle between the exciting force and the motion

$$= \tan^{-1}\frac{2k\Lambda}{1-\Lambda^2}$$



Magnification Factor vs Tuning Factor

Where Λ = tuning factor

$$= \frac{\text{Freq. of encounter}}{\text{Nat. freq.}}$$

$$= \frac{\omega_e}{\omega_z}$$

Added Mass, Damping, Restoring Coefficient and Exciting Forces for Heaving Motions

where $B_n = 2r$ and a_n = added mass of ship section

$$C = \frac{a_n}{\rho\pi\frac{B_n^2}{8}} \quad \text{or} \quad a_n = C.\frac{\rho\pi B_n^2}{8}$$

C for Lewis-form section is obtained from graph provided. as a function of the (draught/beam) ratio and the area coeff. of the section as well as a function of circular frequency of oscillation.

Area coeff. of section,

$$\beta_n = \frac{\text{Section Area}}{B_n \times T_n} = \frac{S_n}{B_n \times T_n}$$

<u>Damping, b</u>

The damping coeff., b can be calculates similar to the case of added mass.

Damping coeff. per unit length, b_n =

$$\frac{\rho.g^2\bar{A}^2}{\omega_e^3}$$

<u>Restoring coefficient, C</u>

$$C = \rho g A_w$$
$$= \rho.g.L.B.C_w$$

Where C_w is waterplane area coeff.

<u>Exciting Force</u>

$F = F_o.\cos\omega_e t$

and $f_o = \frac{F_o}{(\rho g \zeta_a.L.B}$ (Nondimensional form)

$$f_o = \frac{2}{LB}\int_{-L/2}^{L/2} y_{(x)}\cos(kx\cos\mu)dx$$

Pitching Motion

$\theta_a = \theta_{st}.\ \mu_\theta$

Where, θ_{st} = static pitch amplitude = $\frac{M_o}{c}$

μ_θ = magnification factor = $\frac{\theta_a}{\theta_{st}}$

$$\mu_\theta = \frac{1}{\sqrt{(1-\Lambda^2)^2 + 4k^2\Lambda^2}}$$

k = non-dimensional damping factor

$= \frac{\nu}{\omega_\theta}$

The solution of the equation of motion is

$$\theta = B\ e^{-\nu t} \sin(\omega_d.t + \gamma) + C \sin(\omega_e t - \epsilon_2)$$

which, for a steady-state condition (when the first term dies out with time t), is

$\theta = \theta_a \sin(\omega_e.t - \epsilon_2)$ since $C = \theta_a$

or

$$\theta = \frac{\theta_{st}}{\sqrt{(1-\Lambda^2)^2 + 4k^2\Lambda^2}} \sin(\omega_e t - \epsilon_2)$$

ϵ_2 = phase angle between the exciting force and the motion = $\tan^{-1} \frac{2k\Lambda}{1-\Lambda^2}$

The phase angle bet. wave motion and pitching motion,

$$\epsilon = \epsilon_1 + \epsilon_2$$

Virtual Mass Moment of Inertia, Damping, Restoring Coefficient and Exciting Moment

Virtual Mass Moment of Inertia, a

$a = (m + \delta m) \times k_{yy}^2$

$= \frac{\Delta'}{g}.k_{yy}^2$

Damping, b.

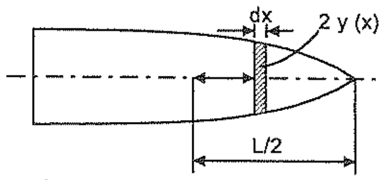
$b'_{pitch} = \frac{b.\sqrt{gL}}{\Delta_B L^2}$

Normally,

$b'_{pitch} = \frac{b}{\rho.\nabla.(L/4)^2\sqrt{g/L}}$

Where,
$\Delta = \rho\nabla = kg$
$L = m$
$g = m/s^2$

Restoring Moment Coefficient, c



Restoring Moment

$= c\theta = \rho.g.\theta.\int_{-L/2}^{L/2} x^2.2y_{(x)}.dx$

$= \rho.g.\theta.I_y$

$c = \Delta_B.GM_L$

Exciting Moment for Pitching, M_θ

$M_o = 2\rho.g.\zeta_a \int_{-L/2}^{L/2} y_{(x)}.x.\sin(kx.\cos\mu).dx$

Non-dimensional amplitude of pitching moment,

$$f_o = \frac{M_o}{\frac{1}{2}.\rho.g.\zeta_a.B.L^2}$$

$$= \frac{4}{B.L^2}\int_{-L/2}^{L/2} y_{(x)}.x.\sin(kx\cos\mu).dx$$

Rolling Motion

Amplitude of roll motion

$\phi_a = \mu_\theta \times \phi_{st}$

Virtual mass moment of Inertia

$I_v = M.k_{xx}^2 + \delta I_{xx}$

$= (\Delta + \delta\Delta)\ k_{xx}^2$

Restoring moment coefficient

$c = \Delta g GM_T$

Tuning factor

$\Lambda = \frac{\omega_e}{\omega_\phi}$

The damping factor is $\kappa = \frac{\upsilon}{\omega_\phi}$ where

$$\upsilon = \frac{b}{2a}$$

Static roll deflection

$$\phi_{st} = \frac{M_o}{c}$$

$$\mu_\theta = magnification\ factor = \frac{\phi_a}{\phi_{st}}$$

$$\mu_\theta = \frac{1}{\sqrt{(1-\Lambda^2)^2 + 4\kappa^2\Lambda^2}}$$

Motion In Irregular Waves

For heave response;

$$m_o = \frac{1}{3} \times C.I. \times \Sigma f(S_R(\omega_E))$$

$$\overline{H}_1 = 2.50\ m_o^{1/2}$$

$$\overline{H}_{1/3} = 4.00\ m_o^{1/2}$$

$$\overline{H}_{1/10} = 5.10\ m_o^{1/2}$$

$$RAO = \frac{\text{Heave Amplitude}}{\text{Wave Amplitude}}$$

For roll response;

$$(\phi)_1 = 1.253\ m_o^{1/2}$$

$$(\phi)_{1/3} = 2.00\ m_o^{1/2}$$

$$(\phi)_{1/10} = 2.545\ m_o^{1/2}$$

$$RAO = \frac{Roll\ Amplitude}{Wave\ Amplitude}$$

Manoeuvrability - Notation Of Force And Moment Derivatives

The following standard notation is used:

e.g. $\frac{\partial Y}{\partial v} = Y_v,\ \frac{\partial N}{\partial \dot\psi} = N_{\dot\psi},\ \frac{\partial N}{\partial \delta_R} = N_{\delta R}$

etc.

Also, for planar motions, $\dot\psi \equiv r\ and\ \ddot\psi \equiv \dot r$

Non-dimensional derivatives:

$$m' = \frac{m}{\frac{\rho}{2}L^3};\ v' = \frac{v}{U};\ \dot v' = \frac{\dot v L}{U^2};\ x_G' = \frac{x_G}{L}$$

$$I_z' = \frac{I_z}{\frac{\rho}{2}L^5};\ r' = \frac{\dot r L}{U};\ \dot r' = \frac{\dot r L^2}{U^2}$$

$$Y_v' = \frac{Y_v}{\frac{\rho}{2}L^2 U};\ Y_r' = \frac{Y_r}{\frac{\rho}{2}L^3 U};\ N_v' = \frac{N_v}{\frac{\rho}{2}L^3 U};\ N_r' = \frac{N_r}{\frac{\rho}{2}L^4 U}$$

$$Y_{\dot v}' = \frac{Y_{\dot v}}{\frac{\rho}{2}L^3 U};Y_{\dot r}' = \frac{Y_{\dot r}}{\frac{\rho}{2}L^4 U};N_{\dot v}' = \frac{N_{\dot v}}{\frac{\rho}{2}L^4 U};N_{\dot r}' = \frac{N_{\dot r}}{\frac{\rho}{2}L^5}$$

$$Y_{\delta R}' = \frac{Y_{\delta R}}{\frac{\rho}{2}L^2 U^2};N_{\delta R}' = \frac{N_{\delta R}}{\frac{\rho}{2}L^3 U^2}$$

The Stability Criterion

For directional stability,

$Y_v' N_r' - (Y_r' - m')N_v' > 0$ (Non-dimensionalised form)

OR

$Y_v\ (N_r - m\, x_G\, u)$ - $N_v\ (Y_r - mu) > 0$

(Origin is not at cg)