NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 2 EXAMINATION 2016-2017

CV4116 - COASTAL ENGINEERING

April / May 2017

Time Allowed: 2½ hours

INSTRUCTIONS

1. This paper contains **FOUR (4)** questions and comprises **FOUR (4)** pages.
2. Answer **ALL** questions.
3. All questions carry equal marks.
4. All answers must be written in the answer book provided.
5. This is a Restricted Open Book Examination. Only **ONE (1) Sheet** of A4 paper with notes on both sides is allowed.
6. A separate booklet of tables and charts is issued together with the paper. Do not write on this booklet.

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1. (a) A record of sea waves, shown in Table Q1, was analysed using the zero down-crossing approach.

Table Q1

Range of Wave Height [m] H	Number of Waves n	nH	nH^2
0.0-0.1	210	10.5	0.525
0.1-0.2	570	85.5	12.825
0.2-0.3	720	180	45
0.3-0.4	630	220.5	77.175
0.4-0.5	420	189	85.05
0.5-0.6	240	132	72.6
0.6-0.7	120	78	50.7
0.7-0.8	90	67.5	67.5
0.8-0.9	0		
0.9-1.0	0		
1.0-1.1	0		
	3000		411.375

$$H_{rms} = \sqrt{411.375 \frac{1}{3000}}$$
$$= 0.370\text{m}$$

$$H_{33} = \frac{67.5+78+132+189+130(0.35)}{1000} = 0.512\text{m}$$

$$H_5 = \frac{67.5 + 60(0.65)}{150} = 0.71\text{m}$$

$$H_1 = \frac{30(0.75)}{30} = 0.75\text{m}$$

(i) What is the total number of waves in this record?

(ii) By approximating the different wave heights as the mid-value in the ranges, calculate H_{rms}, H_{33}, H_5 and H_1,

(12 Marks)

Note: Question No. 1 continues on page 2.

(b) A wave train is approaching a shore with a uniform slope. The wave period is 10 s. At deep water, the wave height H_o is 1 m, and the angle between the bottom contours and wave crests is 15 degree. Assuming that the wave train breaks at H/d = 0.78 where H is the local wave height and d the water depth, calculate the breaking wave height and the angle of approach at the breaking location.

(13 Marks)

$\frac{H_b}{d} = 0.78$

$H_b = 0.78 d_b$

Given T = 10 s

deep water, H_o = 1m

$\alpha_o = 15°$ H_o = 1m

H_b = ?

$k = \frac{2\pi}{L}$

$L_o = \frac{gT^2}{2\pi} = \frac{g(10)^2}{2\pi} = 156.13m$

$\frac{d_b}{gT^2} = \frac{d_b}{g(10)^2}$

$H_b = K_s K_R H_o = 0.78 d_b$

$\sqrt{\frac{1}{\tanh(kd)\left[1+\frac{2kd}{\sinh(2kd)}\right]}} \times \sqrt{\frac{\cos\alpha_o}{\cos\alpha_b}} \times 1.0 = 0.78 d_b$

$\frac{d}{gT^2} = x$

$\frac{d}{gT^2} \times gT^2$

$K_s K_r H_o$	$\frac{d}{gT^2}$	d_b	$0.78 d_b$
1.155	0.001	0.1	0.078
1.35	0.002	1.962	1.53
1.40	0.0018	1.7658	1.38

close enough

$\alpha_b = 3°$

2. (a) Show that the following potential function satisfies the governing Laplace Equation as well as the bottom boundary condition at the seabed. Also show that the kinematic boundary condition at the water surface can be satisfied with this potential function given the dispersion relationship.

$$\phi = \frac{H}{2}\frac{g\cosh k(d+y)}{\sigma\cosh kd}\sin(kx-\sigma t)$$

(10 Marks)

★ Laplace eq:

$\frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} = 0$

$\frac{\partial\phi}{\partial x} = -\frac{H}{2}\frac{g\cosh k(d+y)}{\sigma\cosh(kd)} k\cos(kx-\sigma t)$

$\frac{\partial^2\phi}{\partial x^2} = \frac{H}{2}\frac{g\cosh k(d+y)}{\sigma\cosh kd} k^2\sin(kx-\sigma t)$

$\frac{\partial\phi}{\partial y} = -\frac{H}{2}\frac{g\sin(kx-\sigma t)}{\sigma\cosh kd} k\sinh k(d+y)$

$\frac{\partial\phi^2}{\partial y^2} = -\frac{H}{2} g\frac{\sin(kx-\sigma t)}{\sigma\cosh kd} k^2\cosh k(d+y)$

$= -\frac{H}{2}\frac{g\cosh k(d+y)}{\sigma\cosh kd} k^2\sin(kx-\sigma t)$

$\therefore \frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} = 0$ (Proved)

★ Bottom boundary condition: V = 0 at y = -d

$V = \frac{\partial\phi}{\partial y} = -\frac{H}{2}\frac{g\sin(kx-\sigma t)}{\sigma\cosh kd} k\sinh k(d+y)$

$V|_{y=-d} = -\frac{H}{2} g\frac{\sin(kx-\sigma t)}{\sigma\cosh kd}\sinh(0) = 0$ (proved)

★ Kinematic boundary condition, $V = \frac{\partial\eta}{\partial t}$ at y = 0

$\eta = \frac{H}{2}\cos(kx-\sigma t)$

$\frac{\partial\eta}{\partial t} = -\frac{H}{2}\sigma\sin(kx-\sigma t)$

$V = \frac{\partial\phi}{\partial y} = -\frac{H}{2} g\frac{\sin(kx-\sigma t)}{\sigma\cosh kd} k\sinh k(d+y)$

$V|_{y=0} = -\frac{H}{2} g\frac{\sin(kx-\sigma t)}{\sigma\cosh(kd)} k\sinh kd$

$= -\frac{H}{2\sigma} gk\sin(kx-\sigma t)\tanh kd$

To prove $V = \frac{\partial\eta}{\partial t} \Rightarrow -\frac{H}{2\sigma} gk\sin(kx-\sigma t)\tanh kd$

$= -\frac{H}{2}\sigma\sin(kx-\sigma t)$

(b) A wave train with a deep water wave height H_o of 0.2 m is approaching a shore with a uniform slope of 0.02. The wave crest is parallel to the bottom contours.

(i) If the wave train can be considered as shallow water waves at a water depth of 3 m, calculate the minimum wave period.

(ii) With the wave period in Part b(i), compute the time for the wave train to propagate between two locations with a water depth of 3 m and 2 m, respectively, assuming no wave breaking.

(iii) Is the assumption of no wave breaking valid in Part (b)(ii)? Explain your reasoning.

(15 Marks)

(b) A wave train is approaching a shore with a uniform slope. The wave period is 10 s. At deep water, the wave height H_o is 1 m, and the angle between the bottom contours and wave crests is 15 degree. Assuming that the wave train breaks at H/d = 0.78 where H is the local wave height and d the water depth, calculate the breaking wave height and the angle of approach at the breaking location.

(13 Marks)

2. (a) Show that the following potential function satisfies the governing Laplace Equation as well as the bottom boundary condition at the seabed. Also show that the kinematic boundary condition at the water surface can be satisfied with this potential function given the dispersion relationship.

$$\phi = -\frac{H}{2}\frac{g\cosh k(d+y)}{\sigma\cosh kd}\sin(kx-\sigma t)$$

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(15 Marks)

2) (b) $H_0 = 0.2$

slope = 0.02

(i) $d = 3m$

For shallow water: $\frac{d}{L} < \frac{1}{20}$

$20d < L$

$L > 20 \times 3$

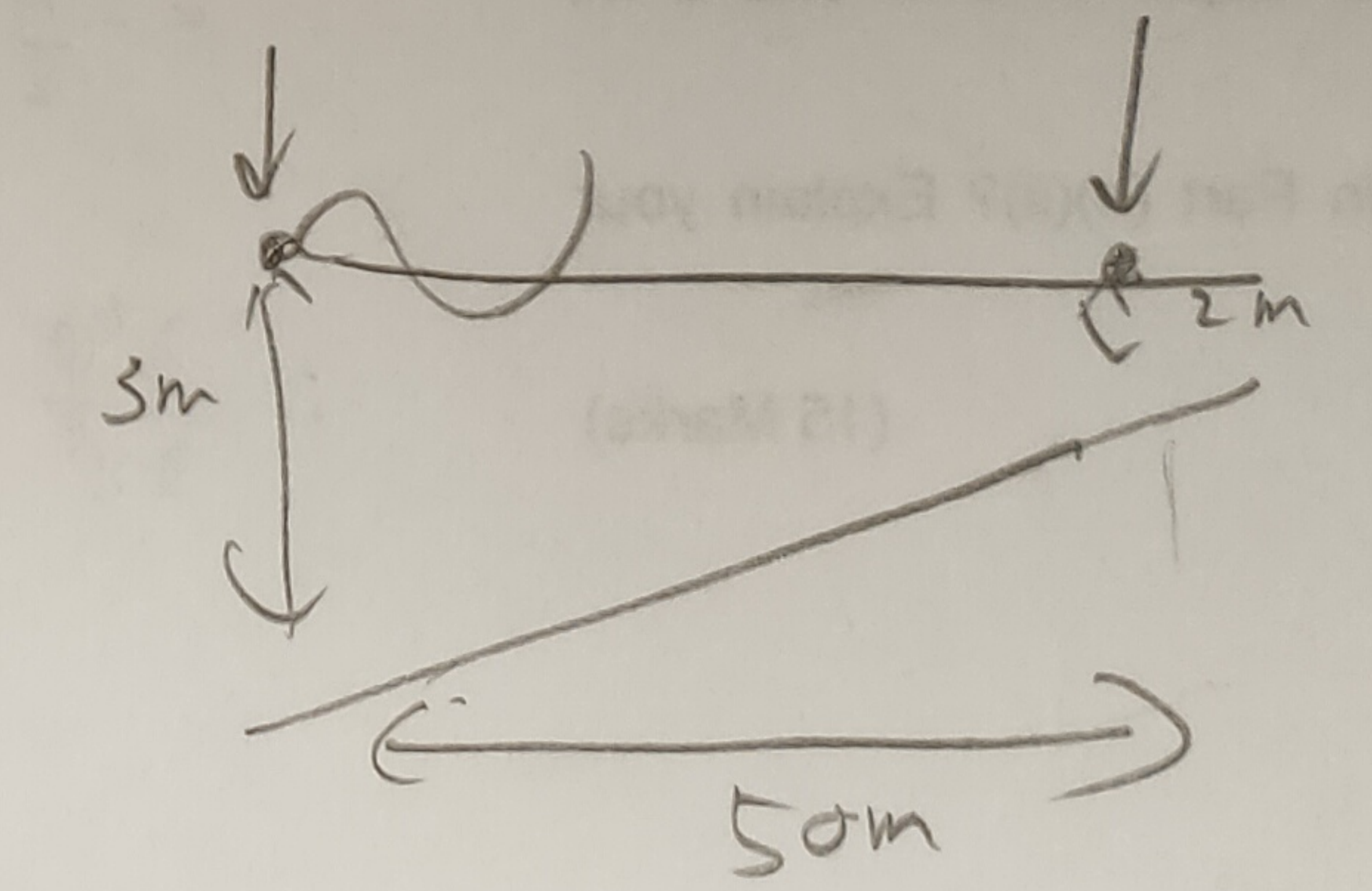
$L > 60m$

$L = T\sqrt{gd}$

$60 = T\sqrt{g(3)}$

$T = 11.06\,s$

(ii)



$t_1 + t_4 = t_2 + t_4 = t_3 + t_4 = t_{AC}$

3. An offshore site is exposed to waves that have a deepwater significant wave height of 0.8 m and a wave period of 5 s. These deepwater waves are approaching from the North-West while the bottom depth contours at the site are parallel and slope northwards towards increasing depth.

(a) Determine the significant wave height at a location close to the shore where the local depth is 7.5 m.

(4 Marks)

(b) A jetty supported by vertical circular piles of diameter 0.5 m is proposed for the site with the local depth of 7.5 m. What is the value of the design wave height you should use for designing the piles? Calculate the maximum horizontal wave force on each of the piles accounting for wave nonlinearity. Assume a seawater specific weight of 10 kN/m³, C_D of 1.0 and C_M of 1.15.

(12 Marks)

(c) A circular vertical floating tank of diameter 3 m and with its bottom extending to 4 m below the still water surface is proposed to be moored at the site. Describe using suitable expressions from linear wave theory, how you would determine the horizontal force induced by the surface waves on the tank. While calculations are not needed, state all significant assumptions used in your approach.

(9 Marks)

4. Two rubble mound breakwaters protect a coastal harbour as shown in Figure Q4. The entire area is dredged to a depth of 5 m below low tide. The largest waves in the area outside the harbour region have a significant wave height of 1.5 m, a wave period of 8 s and wavelength of 45 m. The incident wave directions are from the East (E), Northeast (NE), North (N) and Northwest (NW). Assume the seawater specific weight is 10 kN/m³.

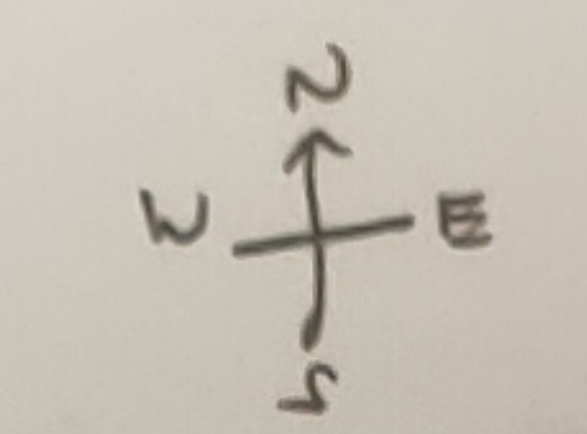
(a) Based on the layout of the breakwater system, indicate from which of the given wave directions would you expect the largest incident waves and briefly explain why. Qualitatively describe the wave protection to the harbour afforded by the breakwaters for each of the given incident wave directions.

(5 Marks)

(b) It is proposed that either the lee side C or lee side D be made into a vertical quay wall so that additional berthing space can be created. Briefly describe how this would affect the wave environment inside the breakwater, and which side you would recommend for the quay wall. Give brief reasons for your recommendation.

(4 Marks)

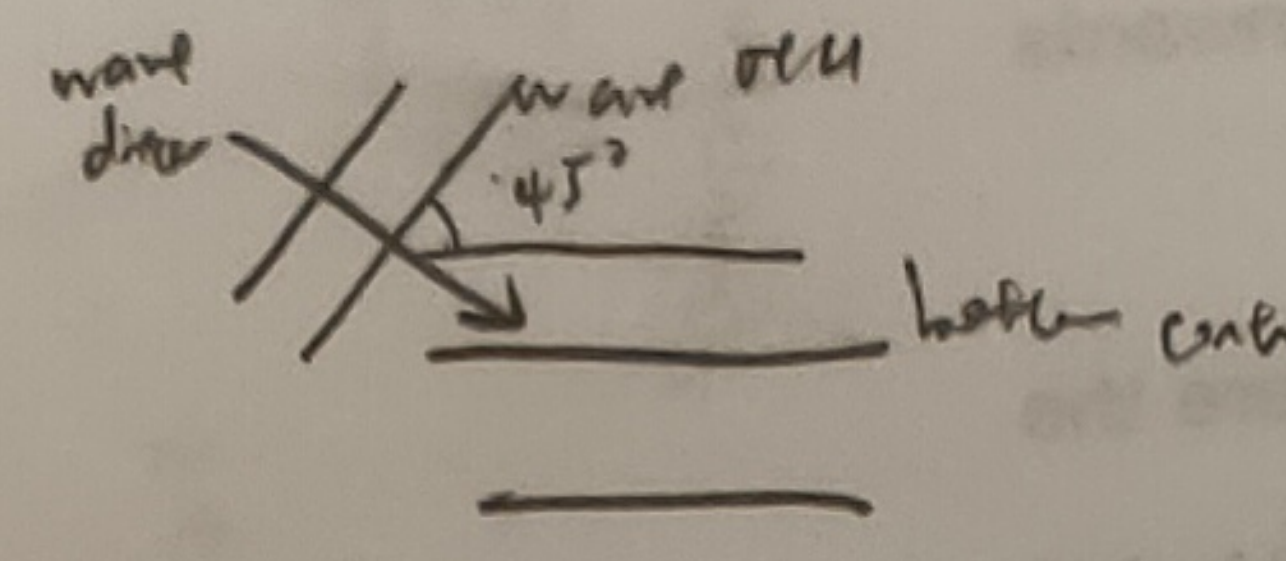
Note: Question No. 4 continues on page 4.



(c)

3) $H_s = 0.8m$

$T = 5s$



(a) $d = 7.5m$

$\frac{d}{gT^2} = \frac{7.5}{g(5)^2} = 0.031$

$H_0 = K_s K_R H_s$

$= (0.87)(0.8)$

$= 0.696$

$\frac{H}{d} = \frac{0.696}{7.5} = 0.0928 < 0.78$ (✗ breaking)

(b) $D = 0.5$

$d = 7.5m$

$\rho g = 10000 \ N/m^3$

$C_D = 1.0$

$C_m = 1.15$

Rigid: $H_{1/100} = 1.67H$

$= 1.67(0.696)$

$= 1.16m$

$L = \frac{gT^2}{2\pi} \tanh\left(\frac{2\pi d}{L}\right)$

$= \frac{g(5)^2}{2\pi} \tanh\left(\frac{2\pi \times 7.5}{L}\right)$

$= 34.32m$

Non-linear dean stream theory

$W = \frac{C_M D}{C_D H} = \frac{1.15(0.5)}{1(1.16)}$

$= 0.5$

SPM Fig VI-5-133

$\frac{d}{gT^2} = 0.0306, \quad \frac{H}{gT^2} = 0.004$

$\phi_M = 0.19$

$\therefore F_M = \phi_M w C_D H^2 D$

$= 0.19(10^4)(1)(1.16)^2(0.5)$

$= 1.28kN$

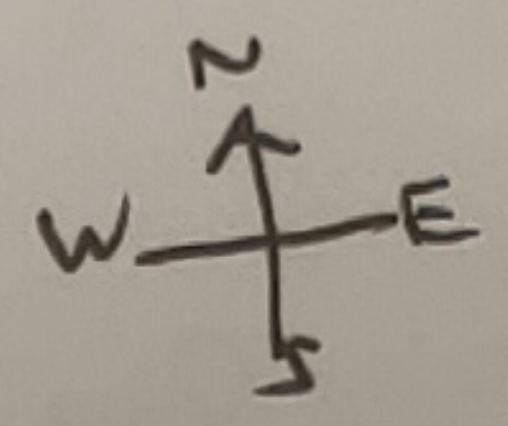
4)

$d = 5m$

$H_s = 1.5$

$T = 8s$

$L = 45$



3. An offshore site is exposed to waves that have a deepwater significant wave height of 0.8 m and a wave period of 5 s. These deepwater waves are approaching from the North-West while the bottom depth contours at the site are parallel and slope northwards towards increasing depth.

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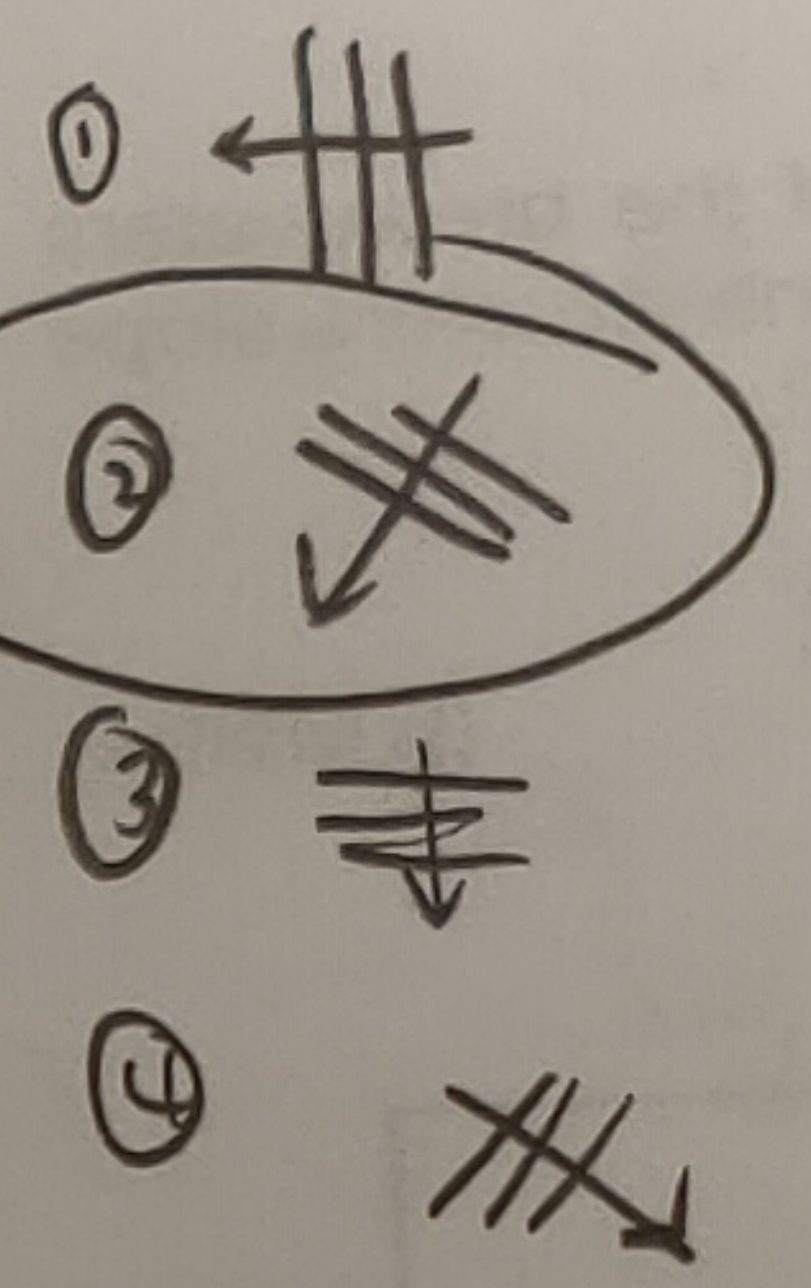
   (9 Marks)



NE-direction

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   (4 Marks)

Note: Question No. 4 continues on page 4.

(c) The gap between the tips of the breakwaters A and B is aligned along the SW to NE direction and with a gap opening of 250 m as sketched in Figure Q4. Estimate the diffracted wave height at the point P arising from waves incident from the NW. The point P is located perpendicular to the gap and 300 m into the harbour as shown. Express you answer as a ratio of the incident wave height.

(7 Marks)

(d) Determine the minimum weight for the primary armour units of the breakwaters assuming that 2 layers of rough angular quarrystones are used, the structure slope is 1V:2H, and the specific weight of the quarrystones is 26 kN/m³.

(9 Marks)

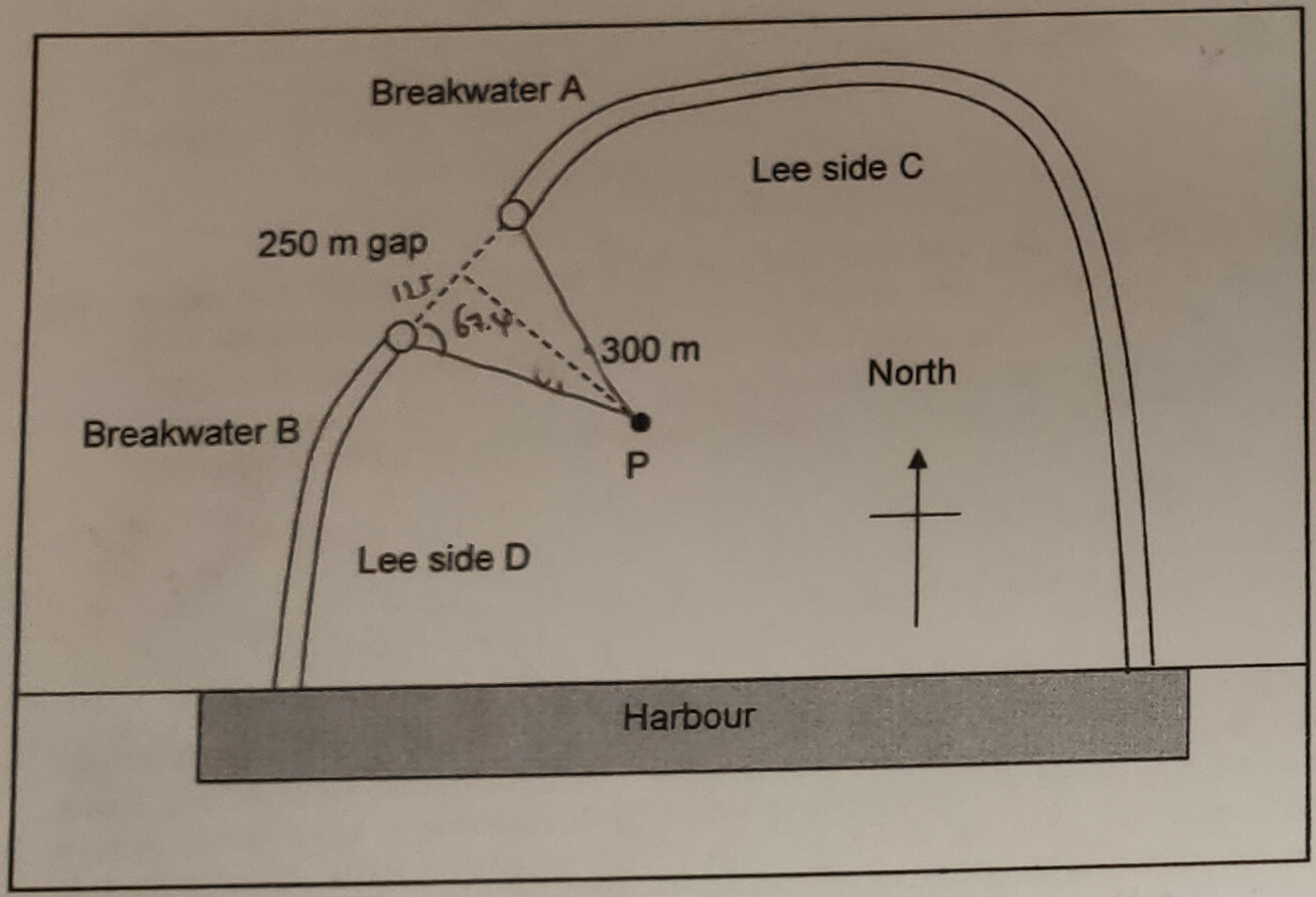


Figure Q4

END OF PAPER

-0.1(45

(c) $L = \frac{gT^2}{2\pi}\tanh\left(\frac{2\pi d}{L}\right)$

$= \frac{g(8)^2}{2\pi}\tanh\left(\frac{2\pi(5)}{L}\right)$

$= 53.08\,m$

Gap width $= 250m > 5L = 5(53.08)$
$= 265.4m$

$R = \sqrt{300^2 + 125^2} = 325$

$\frac{R}{L} = \frac{325}{53.08} = 6.12$

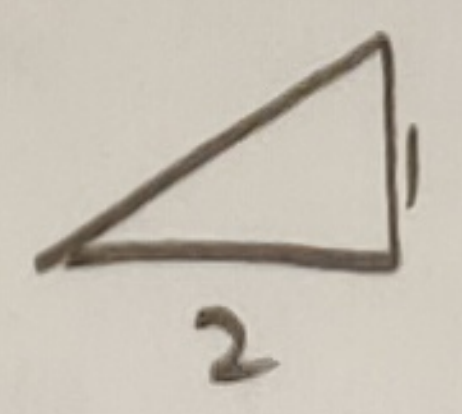
$\beta = 180 - 67.4$
$= 112.6°$

SPM Fig 2-33: $K' = 1.0$ (transmission zone)

$\therefore H_p = K' H_i = 1.0\,(H_i)$
$= H_i$

(d) $H = H_{1/10} = 1.27\,H_s$
$= 1.27\,(1.5)$
$= 1.905m$

Check breaking $= \frac{H}{d} = \frac{1.905}{5} = 0.381 < 0.78$ (X breaking)



Slope 1V: 2H

$\tan\theta = \frac{1}{2}$

$\cot\theta = 2$

Table 7.8: Rough angular, $n = 2$, non-breaking $\rightarrow K_D = 4$ for trunk

Hudson: $M = \frac{\rho_s H^3}{K_D\left(\frac{\rho_s}{\rho_w} - 1\right)^3 \cot\alpha} = \frac{2600\,(1.905)^3}{\underset{\overset{\uparrow}{4}}{K_D}(2.6 - 1)^3 \times 2} = 549kg$