UNIVERSITI TEKNOLOGI PETRONAS

FINAL EXAMINATION
SEPTEMBER 2024 SEMESTER

COURSE	**:**	**VEB4123 - FLOATING OFFSHORE STRUCTURES**
DATE	**:**	**6 DECEMBER 2024 (FRIDAY)**
TIME	**:**	**9.00 AM - 12.00 NOON (3 HOURS)**

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.
6. **You are NOT ALLOWED to bring this final examination question paper out from the Examination Hall.**

Note :

i. There are **TEN (10)** pages in this Question Booklet including the cover page and appendix.

ii. **DOUBLE-SIDED** Question Booklet.

1. Offshore engineering in Southeast Asia, particularly around Malaysia's islands, is influenced by distinct metocean conditions. The region experiences dynamic wave climates due to seasonal monsoons and tropical storms, which impact the design and resilience of offshore structures. Accurate wave analysis is essential for understanding these conditions, allowing engineers to predict wave forces and optimize structural design.

The historical wave data provided in **TABLE Q1** represents wave patterns recorded around a Malaysian island. This data is essential for analysing extreme and typical wave heights and periods, which influence structural safety in the region's offshore platforms. Using the data provided, analyse the following parameters to assess the metocean conditions for the area:

a. Maximum wave height (H_{max}) and maximum wave period (T_{max})

[4 marks]

b. Mean of the highest 10% wave heights ($H_{1/10}$) and periods ($T_{1/10}$)

[4 marks]

c. Significant wave height (H_s) and significant wave period (T_s)

[4 marks]

d. Zero-crossing wave height (H_z) and zero-crossing wave period (T_z)

[4 marks]

e. Provide a brief interpretation of each parameter's relevance for offshore structural design.

[4 marks]

f. Plot a histogram of the wave height using a class interval of 0.1 m and select the wave height range that dominates the region.

[5 marks]

TABLE Q1

Time	Wave height, m	Wave period, s
0:00:00	0.45	3.63
0:15:00	0.47	3.66
0:30:00	0.33	3.46
0:45:00	0.39	3.66
1:00:00	0.66	3.47
1:15:00	0.32	3.5
1:30:00	0.3	3.81
1:45:00	0.33	3.03
2:00:00	0.32	3.42
2:15:00	0.32	2.89
2:30:00	0.27	2.89
2:45:00	0.28	3.08
3:00:00	0.30	3.04
3:15:00	0.28	2.85
3:30:00	0.27	3.28
3:45:00	0.27	2.04
4:00:00	0.32	1.75
4:15:00	0.69	3.47
4:30:00	0.37	1.89
4:45:00	0.36	2.06
5:00:00	0.37	2.08
5:15:00	0.47	1.71
5:30:00	0.29	2.73
5:45:00	0.18	4.75
6:00:00	0.13	2.73
6:15:00	0.42	3.46
6:30:00	0.22	3.46
6:45:00	0.21	3.46
7:00:00	0.44	1.96
7:15:00	0.53	1.93
7:30:00	0.69	2.09
7:45:00	0.52	2.32
8:00:00	0.54	2.52
8:15:00	0.66	2.7
8:30:00	0.67	2.64
8:45:00	0.71	2.64
9:00:00	0.67	2.75
9:15:00	0.65	2.86
9:30:00	0.69	2.82

2. Semi-submersible platforms are frequently used in deepwater offshore projects in Southeast Asia, where water depths can reach beyond 1000 meters. These platforms are exposed to significant wave and current forces, which affect their stability and operational safety. Accurate estimation of horizontal forces on the hull is critical to ensure the platform's integrity, especially in environments with strong currents and varying wave conditions.

FIGURE Q2 illustrates a semi-submersible platform designed for installation at a water depth of 1000 meters, estimate the total horizontal force per unit length exerted on **Hull A** due to wave and current effects at the mid-section after 30 seconds. Assume the hull is a clean member with no marine growth or surface roughness. Justify any engineering considerations or adaptations that may be necessary.

Given data:

- Wave height = 4.3 m
- Wave period = 18 sec
- Current velocity = 12.5 m/s,
- Seawater density = 1.025 t/ m^3

[25 marks]

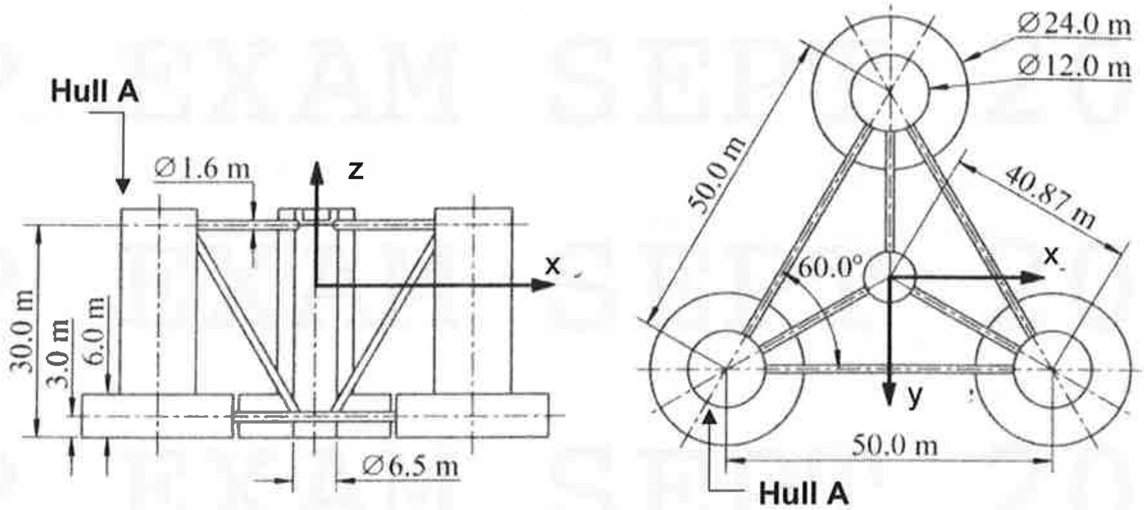

Hull A
Ø1.6 m
z
x
30.0 m
3.0 m
6.0 m
Ø6.5 m
Ø24.0 m
Ø12.0 m
50.0 m
40.87 m
60.0°
x
y
50.0 m
Hull A

FIGURE Q2

3. Tension Leg Platforms (TLPs) are crucial structures in offshore engineering, especially in deepwater oil and gas extraction. The TLP's stability and performance rely on its natural periods, which determine how it will respond to environmental forces like waves, wind, and currents. In Southeast Asia, where variable metocean conditions pose unique challenges, engineers must carefully evaluate the natural periods for motions such as surge, heave, and pitch to ensure the TLP's safety and functionality. **FIGURE Q3** illustrate the details of a tension leg platform (TLP). As an offshore engineer, evaluate the natural period (T_n) of the platform for the surge, heave and pitch motions. Justify any engineering considerations or adaptations that may be necessary.

Given data:

Depth = 500 m

Wave height = 15 m

Wave period = 9 s

ρ = 1.025 t/m^3

C_m = 1.8

Radii of gyration, k_x = 35 m

k_y = 35 m

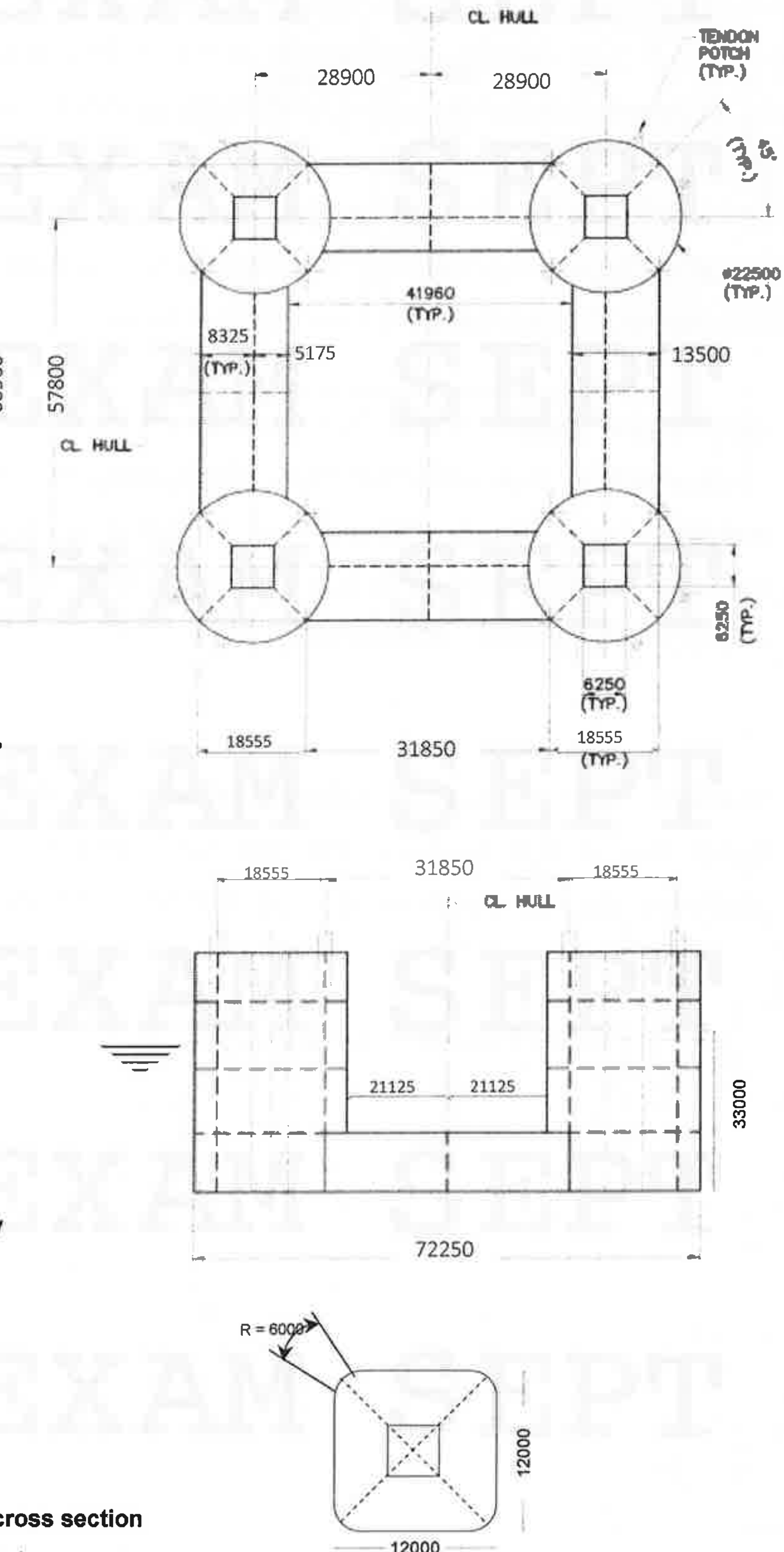
k_z = 42 m

Pitch stiffness = 4x10^8 kN.m/rad

Total Pretension = 18500 t

Axial stiffness per tether = 8500 t/m (one tether for each column)

[25 marks]



Plan View

Side View

Pontoon cross section

(Unit in mm)

FIGURE Q3

4. Tension Leg Platforms (TLPs) are deployed in deepwater environments. Installing a TLP is a complex, multi-stage operation that requires careful planning and execution to ensure structural integrity, stability, and safety in high-risk offshore conditions. Tendon installation, in particular, is a critical aspect of TLP deployment, as it directly influences the platform's tension and stability. A tension leg platform (TLP) was proposed to be installed at the 1300 m depth, 300 km offshore East Coast Malaysia.

a. Identify the stages of the TLP installation process, from initial deployment to final commissioning, highlighting key steps in the installation sequence. Discuss the engineering considerations involved in each stage to ensure platform stability and operational safety in a deepwater environment.

[15 marks]

b. Evaluate **FIVE (5)** specific criteria that must be met during the installation of TLP tendons, and how each criterion impacts the platform's stability, structural integrity, and long-term performance.

[10 marks]

- END OF PAPER -

APPENDIX

RELATIVE DEPTH	SHALLOW WATER $\frac{d}{L} < \frac{1}{25}$	TRANSITIONAL WATER $\frac{1}{25} < \frac{d}{L} < \frac{1}{2}$	DEEP WATER $\frac{d}{L} > \frac{1}{2}$
1. Wave profile	Same As →	$\eta = \frac{H}{2}\cos\left[\frac{2\pi x}{L} - \frac{2\pi t}{T}\right] = \frac{H}{2}\cos\theta$	← Same As
2. Wave celerity	$C = \frac{L}{T} = \sqrt{gd}$	$C = \frac{L}{T} = \frac{gT}{2\pi}\tanh\left(\frac{2\pi d}{L}\right)$	$C = C_o = \frac{L}{T} = \frac{gT}{2\pi}$
3. Wavelength	$L = T\sqrt{gd} = CT$	$L = \frac{gT^2}{2\pi}\tanh\left(\frac{2\pi d}{L}\right)$	$L = L_o = \frac{gT^2}{2\pi} = C_oT$
4. Group velocity	$C_g = C = \sqrt{gd}$	$C_g = nC = \frac{1}{2}\left[1 + \frac{4\pi d/L}{\sinh(4\pi d/L)}\right]\cdot C$	$C_g = \frac{1}{2}C = \frac{gT}{4\pi}$
5. Water Particle Velocity (a) Horizontal	$u = \frac{H}{2}\sqrt{\frac{g}{d}}\cos\theta$	$u = \frac{H}{2}\frac{gT}{L}\frac{\cosh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\cos\theta$	$u = \frac{\pi H}{T}e^{\frac{2\pi z}{L}}\cos\theta$
(b) Vertical	$w = \frac{H\pi}{T}\left(1 + \frac{z}{d}\right)\sin\theta$	$w = \frac{H}{2}\frac{gT}{L}\frac{\sinh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\sin\theta$	$w = \frac{\pi H}{T}e^{\frac{2\pi z}{L}}\sin\theta$
6. Water Particle Accelerations (a) Horizontal	$a_x = \frac{H\pi}{T}\sqrt{\frac{g}{d}}\sin\theta$	$a_x = \frac{g\pi H}{L}\frac{\cosh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\sin\theta$	$a_x = 2H\left(\frac{\pi}{T}\right)^2 e^{\frac{2\pi z}{L}}\sin\theta$
(b) Vertical	$a_z = 2H\left(\frac{\pi}{T}\right)^2\left(1 + \frac{z}{d}\right)\cos\theta$	$a_z = \frac{g\pi H}{L}\frac{\sinh[2\pi(z+d)/L]}{\cosh(2\pi d/L)}\cos\theta$	$a_z = 2H\left(\frac{\pi}{T}\right)^2 e^{\frac{2\pi z}{L}}\cos\theta$
7. Water Particle Displacements (a) Horizontal	$\xi = \frac{HT}{4\pi}\sqrt{\frac{g}{d}}\sin\theta$	$\xi = \frac{H}{2}\frac{\cosh[2\pi(z+d)/L]}{\sinh(2\pi d/L)}\sin\theta$	$\xi = \frac{H}{2}e^{\frac{2\pi z}{L}}\sin\theta$
(b) Vertical	$\zeta = \frac{H}{2}\left(1 + \frac{z}{d}\right)\cos\theta$	$\zeta = \frac{H}{2}\frac{\sinh[2\pi(z+d)/L]}{\sinh(2\pi d/L)}\cos\theta$	$\zeta = \frac{H}{2}e^{\frac{2\pi z}{L}}\cos\theta$
8. Subsurface Pressure	$p = \rho g(\eta - z)$	$p = \rho g\eta\frac{\cosh[2\pi(z+d)/L]}{\cosh(2\pi d/L)} - \rho gz$	$p = \rho g\eta e^{\frac{2\pi z}{L}} - \rho gz$

Summary of Small Amplitude/ Linear (Airy) Wave Theory Expressions

Hydrodynamic Coefficient for Tubular and Non-Tubular Members

Type of members	Drag coefficient	Mass coefficient
Clean tubular members	0.65	1.60
Fouled tubular members	1.05	1.20
Non-tubular members	2.0	2.0

Response Amplitude Operators,

$$RAO = \frac{F/\frac{H}{2}}{[(K - M\omega^2)^2 + (C\omega)^2]^{1/2}}$$

Dynamic Amplification Factor,

$$D.A.F. = \frac{X}{X_s} = \frac{1}{\left\{\left[1 - \left(\frac{\omega}{\omega_n}\right)^2\right]^2 + \left[2\zeta\frac{\omega}{\omega_n}\right]^2\right\}^{1/2}}$$

Lag in phase angle between motion and external force,

$$\tan\beta = \frac{2\zeta\left(\frac{\omega}{\omega_n}\right)}{1 - \left(\frac{\omega}{\omega_n}\right)^2}$$