Model Exam Paper 1

Maximum marks: 100 **Time: 3 hours**
Answer all questions.
No additional support materials are permitted.

PART A (20 × 1 = 20)

1. ________________ are good to transfer applied loads to the foundations of the platform.
2. Compliant platforms are based on a ____________________ concept of design.
3. The design of the geometric form of compliant structures is principally dominated by balancing the __________________ and ________________ of the platform.
4. The ___________________ is a unique component of an articulated tower, which connects it to the foundation system.
5. ___________________ use the friction between two surfaces to dissipate energy.
6. The natural frequency of a system can be measured experimentally using _________________.
7. The yaw response of the deck is attributed to the ______________ in the recentering capability of the buoyant legs under directional wave loads.
8. Due to fluctuating winds, compliant offshore structures are more susceptible to _______________________.
9. The steady wind velocity is measured at _____________________.
10. Wave and wind spectra are ___________ and ____________ banded, respectively.
11. Because a triceratops is a __________________ structure, tether failure will not result in the complete collapse of the structure.

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12. Large, continuous ice sheets called ____________ are formed due to ice cakes freezing together.
13. The ice sheet that remains attached to the shore developed during winter is called ____________.
14. Level ice action induces ________________ in offshore structures.
15. The design guidelines suggest _____________ as the minimum collision energy for the design of offshore structures subject to ship–platform collisions.
16. ______________________ is calculated by multiplying the effective ice pressure and the contact area.
17. ____________ is an appropriate scaling law for inertia and gravity forces.
18. Stiffening the buoyant legs of a triceratops ____________ the tether tension.
19. Cyclic loading in a structural system may lead to ________________.
20. In a BLSRP, the buoyant legs are connected to the deck by_________________.

PART B (10 × 3 = 30)

1. What are the factors that influence the choice of a geometric form for an offshore structure?
2. Explain TLP mechanics.
3. What are viscous fluid dampers?
4. Explain the structural action of a BLSRP.
5. How do you find the damping ratio using the logarithmic decrement method?
6. Why is yaw motion observed in the deck of a BLSRP with a 0° wave heading angle?
7. List the widely used wave spectra in the hydrodynamic analysis of structures.
8. Draw the wind-generated current velocity profile.
9. What are the effects of wind, waves, and currents on sea ice?
10. List the factors that affect the ice load acting on an offshore structure.

PART C (5 × 10 = 50)

1. Briefly explain the structural action of a tension leg platform (TLP).
2. Explain passive control devices.
3. Write briefly about current.
4. Explain the major subsystems in a wind turbine.
5. Expand the following: *FSO, FPSO, FPU, TLP, TLD, TLCD, TMD, MLAT, DVA, BLSRP*.

Model Exam Paper 1: KEY

Maximum marks: 100 **Time: 3 hours**
Answer all questions.
No additional support materials are permitted.

PART A (20 × 1 = 20)

1. *Fixed structures* are good to transfer the applied loads to the foundations.
2. Compliant platforms are based on a *relative displacement* concept of design.
3. The design of the geometric form of compliant structures is principally dominated by balancing the *buoyancy force* and *weight* of the platform.
4. The *universal joint* is a unique component of an articulated tower, which connects it to the foundation system.
5. *Frictional dampers* use the friction between two surfaces to dissipate energy.
6. The natural frequency of a system can be measured experimentally using *free-decay tests.*
7. The yaw response of the deck is attributed to the *time delay* in the recentering capability of the buoyant legs under directional wave loads.
8. Due to fluctuating winds, compliant offshore structures are more susceptible to *low-frequency oscillations*.
9. The steady wind velocity is measured at *10.0 m above MSL*.
10. Wave and wind spectra are *narrow* and *wide* banded, respectively.
11. Because a triceratops is a *positively buoyant* structure, tether failure will not result in the complete collapse of the structure.
12. Large, continuous ice sheets called *ice floes* are formed due to ice cakes freezing together.
13. The ice sheet that remains attached to the shore developed during winter is called *shore-fast ice*.
14. Level ice action induces *random vibrations* in offshore structures.
15. The design guidelines suggest *4.0 MJ* as the minimum collision energy for the design of offshore structures subject to ship–platform collisions.
16. *The maximum crushing ice force* is calculated by multiplying the effective ice pressure and the contact area.
17. *Froude scaling* is an appropriate scaling law for inertia and gravity forces.
18. Stiffening the buoyant legs of a triceratops *increases* the tether tension.
19. Cyclic loading in a structural system may lead to *fatigue failure.*
20. In a BLSRP, the buoyant legs are connected to the deck by *hinged joints*.

PART B (10 × 3 = 30)

1. What are the factors that influence the choice of a geometric form for an offshore structure?

a) *Structural form with a stable configuration*
b) *Geometric form leading to low installation, fabrication, and decommissioning costs*
c) *Geometric form that requires a lower CAPEX and leads to a high return on investment (ROI)*
d) *Geometric form that can result in an early start for production and that possesses high mobility*
e) *Geometric form that requires the least possible intervention, so that uninterrupted production can take place*

2. Explain TLP mechanics.

When no load is applied on the structure, the structure is in a stationary, stable condition. Due to excess buoyancy, the tethers are in high tension so that the platform is held down to the seabed. Under lateral loading from wind, waves, or currents, the structure experiences a lateral displacement. The lateral displacement of the TLP is called offset. The offset condition of the TLP pulls down the structure. The vertical displacement is called setdown.

3. What are viscous fluid dampers?

- *A viscous fluid damper is similar to a conventional shock-absorber. It consists of a closed cylinder-piston, which is filled with fluid (usually silicon oil).*
- *These dampers are typically installed as diagonal braces in building frames (preferably steel structures).*
- *To provide optimal damping, buildings are often equipped with multiple dampers in place of diagonal beams on every floor.*

4. Explain the structural action of a BLSRP.

The structural action of a BLSRP under lateral loads is similar to other compliant offshore structures:

a) *It is similar to a TLP, because a restraining system with tethers is common.*
b) *It is similar to a spar platform, because each buoyant leg resembles a spar buoy due to the deep draft.*
c) *It has articulated towers due to the presence of hinged joints. Therefore, a BLSRP is a hybrid compliant platform.*

5. How do you find the damping ratio using the logarithmic decrement method?

The damping ratio in the respective DOF is obtained by the logarithmic decrement method and is as follows:

$$\delta = \frac{1}{n} ln\left(\frac{x_0}{x_n}\right)$$

where x_0 is the higher value of the two peaks. x_n is the value of the peak after n cycles. The damping ratio is determined by:

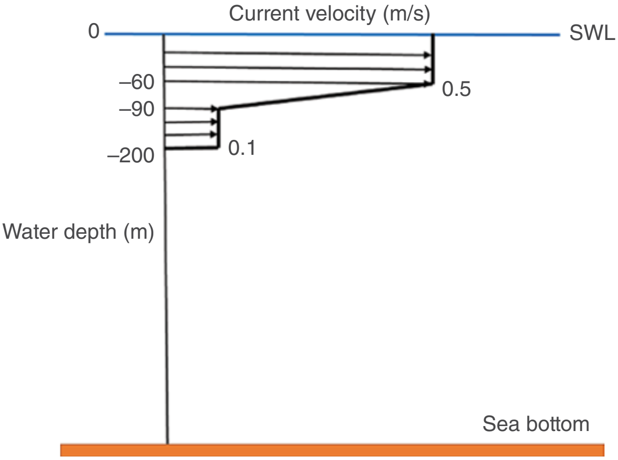
$$\zeta = \frac{1}{\sqrt{1+\left(\frac{2\pi}{\delta}\right)^2}}$$

6. Why is yaw motion observed in the deck of a BLSRP with a 0° wave heading angle?
As buoyant legs are symmetrically spread with respect to the vertical axis of the platform, it is imperative to envisage a non-uniform phase lag in the recentering process; this causes the yaw motion of the deck.

7. List the widely used wave spectra in the hydrodynamic analysis of structures.

a) *Pierson-Moskowitz (PM)*
b) *JONSWAP*
c) *ISSC*
d) *Bredneidger*
e) *Ochi-Hubble*

8. Draw the wind-generated current velocity profile.



9. What are the effects of wind, waves, and currents on sea ice?

- *The exposure of developed ice to the wind, waves, and currents lead to the deformation of the ice along with an increase in the brittleness of the ice crust.*
- *The continuous action of wind, waves, and currents transforms this continuous flat ice sheet into pressure ice fields with rough surfaces.*

10. List the factors that affect the ice load acting on an offshore structure.

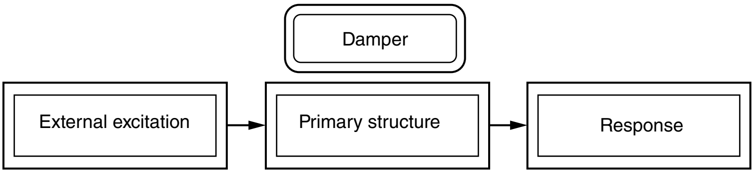
a) *Structural geometry of the platform*
b) *Location and environmental conditions*
c) *Ice properties such as thickness, velocity, and crushing strength*
d) *Ice–structure interaction phenomena*

PART C (5 × 10 = 50)

1. Briefly explain the structural action of a tension leg platform (TLP).

Tension leg platforms (TLPs) operate successfully in deep water. They are classified as hybrid compliant structures that are suitable for both drilling and production operations. Compliancy of the platform is restricted to the surge, sway, and yaw DOF, while the heave, roll, and pitch DOF remain stiff. This compliancy is obtained using taut-moored pre-tensioned tethers that hold the platform in position. The tethers connect the platform column to the seabed through the pile templates. The axial stiffness of the tether is kept significantly high to counteract the excessive buoyancy inherent in the design. Tension in the tethers minimizes the motion of the platform in the vertical plane, while excessive buoyancy helps the tethers to remain stiff; hence the name TLP. The TLP concept is designed in such a manner that the natural periods of the platform are either too low or too high in comparison to the operational wave periods.

2. Explain passive control devices.



Passive systems require no external energy for successful operation, which is one of the major advantages of such systems in comparison to other types. A key benefit of passive control devices is that once installed in a structure, they do not require any startup or operation energy, unlike active and semi-active systems. Passive control devices are active at all times until maintenance, replacement, or dismantling is required.

Passive control systems include friction dampers, metallic yield dampers, and viscous fluid dampers. Alternative types of passive control systems contain a spring (or spring-like component), which is tuned to a particular natural frequency of the structure for maximum damping. Examples of these passive control devices are tuned mass dampers, tuned liquid dampers, and tuned liquid column dampers.

3. Write briefly about current.
Current generation in the sea is mainly due to the following factors:

- *Wind effects*
- *Tidal motion*
- *Temperature differences*
- *Density gradients*
- *Salinity variations*

The apparent wave period and the total water particle velocity are altered by the presence of currents. The current action also imposes additional drag forces on structures, which in turn affects the tether tension variation of compliant structures. Wind-generated currents are highly concentrated close to the sea surface, and the effect decreases with increased water depth. The current effect is included in the analysis by representing the current velocity, which varies linearly from the maximum value at the sea surface to zero at the seabed. The maximum current velocity of wind-generated current can be approximated as 1.0–3.0% of the sustained wind velocity. The current in the same direction as the waves increases the wavelength and the wave period. The increased wave period (10%) due to current action is called the apparent wave period.

4. Explain the major subsystems in a wind turbine.
The seven major subsystems in a wind turbine are as follows:

- *Blades*
- *Nacelle*
- *Controller*
- *Generator*
- *Rotor*
- *Tower*
- *Floating body*

The rotor houses a number of blades that determine the system performance of the wind turbine. A three-bladed upwind design is predominantly used in the design of the rotor, and the blade design is usually based on the pitch control. The nacelle protects the generator, controller, gearbox, and shafts. The tower *supports the wind turbine nacelle and rotor. The total height of the tower at the particular site is usually governed by the rotor diameter and the nature of the loading conditions. Generators are used to convert the raw mechanical work of the wind turbine to useful electrical output. Changes in the blade pitch angle, generator loading, and nacelle yaw are monitored by the control system. The generated electrical output is transferred to a suitable electrical grid through cables buried in the seabed. If this method is uneconomical, in recent years the generated power has been transferred through battery storage. The wind turbine elements are supported on a floating body, and mooring systems are usually employed to position restrain the system.*

5. Expand the following:
FSO – Floating storage and offloading
FPSO – Floating production, storage, and offloading
FPU – Floating production unit
TLP – Tension leg platform
TLD – Tuned liquid damper
TLCD – Tuned liquid column damper
TMD – Tuned mass damper
MLAT – Multi-leg articulated tower
DVA – Dynamic vibration absorber
BLSRP – Buoyant leg storage regasification platform

Model Exam Paper 2

Maximum marks: 100 **Time: 3 hours**

Answer all questions.

No additional support materials are permitted.

PART A (20 × 1 = 20)

1. _____________ are insensitive under lateral loads arising from wind, waves, and currents.
2. Why is recentering considered important in the design of compliant structures?
3. Articulated towers are similar to TLPs, with tethers replaced by a ________________.
4. Metallic yield dampers are known to have ________________ behavior.
5. When the frequency of the tank motion is closer to one of the natural frequencies of the tank fluid, ________________________ occurs.
6. Higher stiffness in the yaw motion of a BLSRP is due to the _______________ of the buoyant legs.
7. Because the BLSRP is positive-buoyant, ___________________ on the tethers is necessary to ensure position restraint.
8. The wind load acting on the deck of the platform will induce additional moment, resulting in ______________________.
9. The maximum current velocity of the wind-generated current can be approximated as _____________ of the sustained wind velocity.
10. With an increase in the severity of the sea conditions, the ______________ in the surge DOF of the triceratops increases.
11. The design of offshore structures is mainly governed by these forms of ice: __________, __________, and ______________.
12. When the ice force frequency becomes equal to the natural frequency of the structure, the ____________________ of the structural force will be high.
13. In the case of a three-legged structure like a triceratops, the maximum ice force occurs when ice acts on ____________________.
14. In a wind turbine, the ___________ houses a number of blades that determines the system performance.
15. Current action imposes additional __________ forces on the structure.
16. A ___________________ is a passive type of damper that imposes response control using the principal of inertia.
17. The heave natural period is reduced by _____________ the pipe wall thickness of the tethers.

18. Among the wind spectra, lower spectral energy is observed in the __________________.
19. Compliant platforms are position-restrained by _____________.
20. Hinged joints also serve as ________________, which controls the deck motion even for a large movement/rotation of the buoyant legs.

PART B (10 × 3 = 30)

1. How do you classify offshore structures based on station-keeping characteristics?
2. Name some semi-active control devices.
3. What are the advantages of a MLAT?
4. What is the major reason for the differences in responses of buoyant legs?
5. Write the canonical form of the Mathieu equation.
6. List the wind spectra used to represent random wind for the analysis of structures.
7. Differentiate pancake ice and ice cakes.
8. Explain the formation of icebergs.
9. Differentiate limit stress and limit force failure.
10. List the disadvantages of offshore wind turbines.

PART C (5 × 10 = 50)

1. Write briefly about the spar platform.
2. Describe tuned mass dampers.
3. How is the service life of the structure calculated based on fatigue analysis?
4. How does an increase in temperature affect material properties?
5. Expand the following: *FSRU, FLNG, PM, IFFT, API, RAO, IEC, HAWT, VAWT, RNA*

Model Exam Paper 2: KEY

Maximum marks: 100 **Time: 3 hours**

Answer all questions.

No additional support materials are permitted.

PART A (20 × 1 = 20)

1. *Fixed platforms* are insensitive under lateral loads arising from wind, waves, and currents.

2. Why is recentering considered important in the design of compliant structures? *It is very important in the context of compliant platform design because large displacements are essentially permitted as a part of the design itself.*
3. Articulated towers are similar to TLPs, with tethers replaced by a *single high-buoyancy shell*.
4. Metallic yield dampers are known to have *stable hysteretic* behavior.
5. When the frequency of the tank motion is close to one of the natural frequencies of the tank fluid, *large-amplitudes sloshing* occurs.
6. Higher stiffness in the yaw motion of a BLSRP is due to the *symmetric layout* of the buoyant legs.
7. Because the BLSRP is positive-buoyant, *high initial pre-tension* on the tethers is necessary to ensure position restraint.
8. The wind load acting on the deck of the platform will induce additional moment, resulting in *an excessive pitch response*.
9. The maximum current velocity of the wind-generated current can be approximated as *1.0–3.0%* of the sustained wind velocity.
10. With the increase in the severity of the sea conditions, the *mean shift* in the surge DOF of the triceratops increases.
11. The design of offshore structures is mainly governed by these forms of ice: *ice sheets*, *pack ice*, and *icebergs*.
12. When the ice force frequency becomes equal to the natural frequency of the structure, the *dynamic amplification* of the structural force will be high.
13. In the case of a three-legged structure like a triceratops, the maximum ice force occurs when ice acts on *two buoyant legs simultaneously*.
14. In a wind turbine, the *rotor* houses a number of blades that determine the system's performance.
15. Current action imposes additional *drag* forces on the structure.
16. A *tuned mass damper (TMD)* is a passive type of damper that imposes response control using the principle of inertia.
17. The heave natural period is reduced by *increasing* the pipe wall thickness of the tethers.
18. Among the wind spectra, lower spectral energy is observed in the *Davenport spectrum*.
19. Compliant platforms are position-restrained by *tethers.*
20. Hinged joints also serve as *isolators*, which controls the deck motion even for a large movement/rotation of the buoyant legs.

PART B (10 × 3 = 30)

1. How do you classify offshore structures based on station-keeping characteristics?
   Fixed, compliant, and floating types

2. Name some semi-active control devices.

   Variable orifice fluid dampers, controllable friction devices, variable stiffness devices, controllable fluid dampers, and magneto-rheological dampers

3. What are the advantages of a MLAT?

   The payload and deck areas can be increased and made comparable to conventional production platforms in moderate water depths, and the sway or horizontal displacement of the deck is considerably reduced compared to single-leg articulated towers.

4. What is the major reason for the differences in responses of buoyant legs?

   Differences in the responses of buoyant legs are due to the variable submergence effect, which is one of the primary sources of nonlinearity in the excitation force.

5. Write the canonical form of the Mathieu equation.

   The Mathieu equation is a special form of the Hill equation, with only one harmonic mode. The canonical form is given by:

   $$\frac{d^2 f}{d\tau}+\left(\delta - q\,Cos\left(2\tau\right)\right)f=0$$

   where $\boldsymbol{\delta}$ *and* $\boldsymbol{q}$ *are Mathieu parameters, which are problem-specific.*

6. List the wind spectra used to represent random wind for the analysis of structures.
   - *Davenport spectrum*
   - *Harris spectrum*
   - *Kaimal spectrum*
   - *Simiu spectrum*
   - *Kareem spectrum*
   - *American Petroleum Institute (API) spectrum*

7. Differentiate pancake ice and ice cakes.

   Circular ice pieces of diameter up to 3.0 m are called pancake ice, and larger pieces are called ice cakes. Pancake ice causes impact forces on offshore structures, which increase with increased wave height and current field.

8. Explain the formation of icebergs.

   Icebergs form due to the flow of glaciers followed by chunks of ice breaking due to the buoyancy of water. The direction and amplitude of wind and *currents govern the velocity of the icebergs in a particular location. The temperature variation above and below the water surface causes non-uniform melting of icebergs, which results in icebergs tilting, capsizing, and breaking. Breakage of icebergs leads to the formation of smaller bergs called growlers or bergy bits.*

9. Differentiate limit stress and limit force failure.

- *In the case of limit stress failure, ice sheet failure occurs at the ice–structure interface when the environmental forces acting on the ice are greater than the failure strength of the ice. The common modes of ice failure given limit stress failure conditions are buckling and crushing.*
- *In the case of limit force failure, the ice failure occurs far from the ice–structure interface, and the environmental forces acting on the ice sheet lead to the formation of ice ridges.*

10. List the disadvantages of offshore wind turbines.

- *Very high initial investment*
- *Complications involving the construction of the foundation and supporting structure, commissioning, and decommissioning*
- *Less accessibility compared to onshore wind farms, which in turn increases downtime and increases the cost of maintenance and operation*
- *Complexities arising due to the extreme hydrodynamic and aerodynamic loads acting on the supporting structures and turbines*

PART C (5 × 10 = 50)

1. Write briefly about the spar platform.

A spar platform is a large, deep-draft, cylindrical floating caisson, generally used for exploration and production purposes and installed at water depths of a few thousand meters. A spar has a long cylindrical shell called a hard tank, which is located near the water level. It generates high buoyancy for the structure, which helps keep the platform stable; the midsection is annulled and free flooding. The bottom part is called a soft tank and is utilized for placing the fixed ballast. It essentially floats the structure during transport and installation. In order to reduce the weight, drag, and cost of the structure, the midsection is designed to be a truss structure. To reduce the heave response, horizontal plates are introduced between the truss bays. The cell spar is the third generation of spar platforms, which was commissioned in 2004. It has a number of ring-stiffened tubes that are connected by horizontal and vertical plates. The hull is transported to the offshore site horizontally on its side.

2. Describe tuned mass dampers.

A tuned mass damper (TMD) is a passive type of damper that imposes response control using the principle of inertia. A TMD applies indirect damping to the structural system. The inertial force of the damper is equal to and opposite the excitation force for optimum control. TMDs are used for structures under lateral loads. A TMD consists of a secondary mass attached to the main structure through a spring-dashpot arrangement.

The energy of the primary structure is dissipated by inertial forces produced by the damper. The damper produces an inertial force in the direction opposite that of the structure's motion. The inertial force in the opposite direction helps reduce the motion of the primary structure. For maximum response reduction, the parameters of the TMD need to be tuned with those of the primary structure. The support system for the mass and tuning the frequency are important issues in the design of TMDs. While the mass of the damper is taken as a small fraction of the total mass of the primary structure (usually 1–5%), one of the main limitations is its sensitivity to the narrow frequency band of control. Mistuning of the TMD reduces its effectiveness considerably.

3. How is the service life of the structure calculated based on fatigue analysis?

The steps involved in the fatigue analysis of tethers are as follows:

Step 1: Dynamic response analysis of the triceratops

The dynamic response analysis of the triceratops should be carried out under the action of either environmental loads or accidental loads through experimental or numerical investigations.

Step 2: Tether tension variation

The tension variation of a tether should be obtained from the investigations carried out on the structure.

Step 3: Tether stress time history

From the known area of the tether and the tether tension variation, the tether stress variation time history is obtained.

Step 4: Stress histogram

The stress histogram should be developed from the stress time history. This stress histogram gives the stress range with the number of cycles.

Step 5: Allowable stress cycles

The allowable stress cycles should be calculated according to the standard regulations using the S-N curve approach. It is given by:

$$\log N = \log B - m \log S$$

where N is the number of allowable cycles, S is the stress range, and B and m are constants obtained from the S-N curves.

Step 6: Fatigue damage assessment

The fatigue damage of the tether is then calculated using the Miner-Palmgren rule given by:

$$D_f = \sum_{i=1}^{m} \frac{n_i}{N_i}$$

where Df is the fatigue damage, n is the number of stress counts from the histogram, and N is the number of allowable cycles from the S-N relationship.

Step 7: Service life calculation

Fatigue damage is then calculated for one year. Finally, the service life of the tethers is calculated by extrapolating the fatigue damage to one tether.

4. How does an increase in temperature affect material properties?

Offshore structures, especially the topsides, are constructed with different forms of steel. With respect to the grade of steel, the stress–strain characteristics vary significantly at elevated temperatures. Increased temperatures lead to thermal strains in the material, even in the absence of mechanical loading. So, the structural elements experience thermal strain without an increase in internal stresses under higher temperatures.

With the increase in temperature, Young's modulus, stiffness, and the yield strength of the structural steel decrease, with or without the development of mechanical strains. On the other hand, the material ductility increases, showing an indication of strength development.

In the case of mild carbon steel, the effective yield strength is reduced at higher temperatures (greater than 400 oC) at 2% strain, whereas the proportional limit and modulus of elasticity decrease with temperatures over 100 oC.

5. Expand the following:

FSRU – Floating storage and regasification unit
FLNG – Floating liquefied natural gas
PM – Pierson-Moskowitz
IFFT – Inverse fast Fourier transform
API – American Petroleum Institute
RAO – Response amplitude operator
IEC – International Electro-Technical Commission
HAWT – Horizontal axis wind turbine
VAWT – Vertical axis wind turbine
RNA – Rotor nacelle assembly

Model Exam Paper 3

Maximum marks: 100 **Time: 3 hours**
Answer all questions.
No additional support materials are permitted.

PART A (20 × 1 = 20)

1. ________________ are insensitive under lateral loads arising from wind, waves, and currents.
2. A __________________design approach is popularly used to design fixed platforms so they exhibit very low displacements under lateral loads.
3. ___________________ help restore dynamic equilibrium in the system under various environmental loads.
4. In a spar platform, a ____________ generates high buoyancy for the structure.
5. ___________________, _________________, and _________________ are passive control devices.
6. Buoyant legs are an alternative structural form of __________ platforms.
7. ________________ isolate the deck and buoyant legs in a BLSRP and provide operational comfort.
8. The stress range and the number of cycles are estimated using ______________________.
9. Random waves are usually described using statistical parameters such as ____________________ and ___________________.
10. The average wind velocity occurring over one hour is taken as the _______________.
11. A triceratops is _____________ in the translational DOF.
12. The peaks in the response spectrum usually occur at _____________.
13. Ice floes freezing together results in the formation of ______________ covering more than 10 km.
14. _________________ controls an ice floe's impact on an offshore structure.
15. Ice failure occurs due to _____________ and ____________ modes at lower and higher strain rates, respectively.
16. An increase in ice velocity _______________ the average crushing force.
17. The principal mechanism that causes a reduction in the strength and stability of a structure during a fire is _______________________.
18. Young's modulus, stiffness, and the yield strength of structural steel _____________ with an increase in temperature.

19. Ring stiffeners prevent damage from spreading to the adjacent bay and act as an obstruction to ____________________.
20. The suitability of pontoon wind turbines is limited to ______________.

PART B (10 × 3 = 30)

1. Differentiate elasticity and recentering.
2. What is a shallow TLD?
3. List the major components in the deck of a BLSRP.
4. Why are rotational responses observed in the deck of a BLSRP, despite the presence of hinged joints?
5. Explain the PM spectrum and its applicability.
6. What is the apparent wave period?
7. What are the special loads that act on offshore structures?
8. Explain the ice–structure interaction phenomenon.
9. List the ice failure modes.
10. What are the advantages of offshore wind turbines?

PART C (5 × 10 = 50)

1. Describe active control systems with a neat sketch.
2. Write briefly about a TLCD.
3. What are the advantages of a TLP with a TMD?
4. Describe the response behavior of a BLSRP under wave loads.
5. Explain the continuous ice crushing phenomenon.

Model Exam Paper 3: KEY

Maximum marks: 100 **Time: 3 hours**

Answer all questions.

No additional support materials are permitted.

PART A (20 × 1 = 20)

1. *Fixed platforms* are insensitive under lateral loads arising from wind, waves, and currents.
2. A *strength-based* design approach is popularly used to design fixed platforms so they exhibit very low displacements under lateral loads.
3. *Large displacements* help restore dynamic equilibrium in the system under various environmental loads.

4. In a spar platform, a *hard tank* generates high buoyancy for the structure.
5. *Tuned mass dampers*, *tuned liquid dampers,* and *tuned liquid column dampers* are passive control devices.
6. Buoyant legs are an alternative structural form of *spar* platforms.
7. *Hinged joints* isolate the deck and buoyant legs in a BLSRP and provide operational comfort.
8. The stress range and the number of cycles are estimated using *the rainflow-counting method.*
9. Random waves are usually described using statistical parameters such as *significant wave height* and *zero-crossing periods*.
10. The average wind velocity occurring over one hour is taken as the *steady wind velocity*.
11. A triceratops is *monolithic* in the translational DOF.
12. The peaks in the response spectrum usually occur at *multiples or fractions of the natural frequency of the structure or the dominant wave frequency*.
13. Ice floes freezing together results in the formation of *ice fields* covering more than 10 km.
14. *Drift velocity* controls an ice floe's impact on an offshore structure.
15. Ice failure occurs due to *creep* and *crushing* modes at lower and higher strain rates, respectively.
16. An increase in ice velocity *decreases* the average crushing force.
17. The principal mechanism that causes a reduction in the strength and stability of a structure during a fire is *the release of potential energy*.
18. Young's modulus, stiffness, and the yield strength of structural steel *decrease* with an increase in temperature.
19. Ring stiffeners prevent damage from spreading to the adjacent bay and act as an obstruction to *circumferential bending*.
20. The suitability of pontoon wind turbines is limited to *calm seas*.

PART B (10 × 3 = 30)

1. Differentiate elasticity and recentering.

   Elasticity refers to material characteristics and ensures that a member regains its form, shape, and size upon the removal of loads, when the applied load is within the elastic limit. Recentering is an extension of this property.

   Recentering refers to the capability of the structural form (not a material characteristic) to regain its initial position (which may not be an equilibrium position) in the presence of external forces (not upon their removal, unlike in elasticity).

2. What is a shallow TLD?

   If the ratio of the height of the liquid column in a damper to the length of the tank (in the case of a rectangular tank) or the diameter of the circular tank is less than 0.15, then it is classified as a shallow water tuned liquid damper.

3. List the major components in the deck of a BLSRP.
   The deck has utilities including a regasification unit, a gas turbine with a generator, air compressors, fuel pumps, a fire water and foam system, a fresh water system, cranes, a lubrication oil system, lifeboats, a helipad, and a LNG tank.

4. Why are rotational responses observed in the deck of a BLSRP, despite the presence of hinged joints?
   The presence of rotational responses in the deck, despite the presence of hinged joints, is due to the differential heave response that occurs due to dynamic tether tension variations.

5. Explain the PM spectrum and its applicability.
   The most commonly used wave spectrum in offshore design is the PM spectrum, which is applied in different regions such as the Gulf of Mexico, offshore Brazil, Western Australia, offshore Newfoundland, and Western Africa in both operational and survival conditions. This spectrum is suitable for representing open sea conditions that are neither fetch limited nor duration limited.

6. What is the apparent wave period?
   Current in the same direction as waves increases the wavelength and the wave period. The increased wave period (10%) due to the current action is called the apparent wave period.

7. What are the special loads that act on offshore structures?
   - *Environmental loads due to ice, earthquakes, tides, and marine growth*
   - *Loads due to temperature variations and seafloor movement*
   - *Accidental loads due to ship–platform collisions, dropped objects, fires, explosions, changes of intended pressure differences during drilling, and failure of mooring lines in the case of compliant structures*

8. Explain the ice–structure interaction phenomenon.
   When an ice sheet hits a vertical structure under the action of wind, waves, and currents, continuous failure of the ice occurs, which results in a horizontal force on the structure. Under certain conditions, the ice–structure interaction may also result in transient vibrations due to pressure gradients developed from the continuous failure of the ice.

9. List the ice failure modes.
   - *Crushing*
   - *Buckling*
   - *Shear*

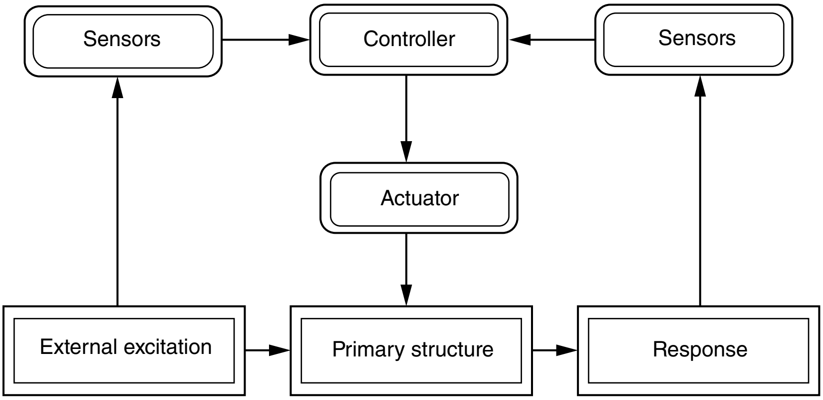
- *Radial and circumferential cracking*
- *Creep*
- *Spalling*

10. What are the advantages of offshore wind turbines?

- *Less intense sea turbulence*
- *Fewer constraints on the size of the wind turbines*
- *Avoidance of noise and visual disturbances due to the distance from shore*

PART C (5 × 10 = 50)

1. Describe active control systems with a neat sketch.



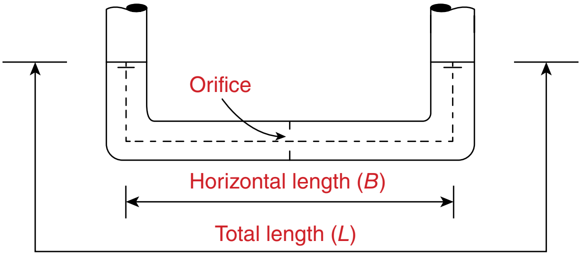
An active control system consists of three major components:

- *The monitoring system can perceive the present condition of the structure and subsequently record the data using an electronic data acquisition system.*
- *The control system decides what reaction forces to apply to the structure based on communications received from the monitoring system.*
- *The actuating system applies physical forces to the structure as directed by the control system.*

To accomplish all these things, an active control system needs a continuous external power source. The loss of power that might be experienced during a catastrophic event may render these systems ineffective.

Common examples of active control systems are active mass dampers and active liquid dampers.

2. Write briefly about a TLCD.



A tuned liquid column damper (TLCD) is a U-shaped tube half-filled with liquid. Unlike a TLD, which depends on liquid sloshing dampening structural vibrations, a TLCD controls structural motion by a combined action of the movement of liquid in the tube and the loss of pressure due to the orifice inside the tube.

A nozzle is placed at the horizontal part of the tube. The extent of response control achieved by a TLCD depends on the frequency of the exciting force acting on the structure.

While the restoring force is developed by the gravitational force acting on the liquid, the orifice is the controlling element for the dynamics of the liquid sloshing inside the tube. Damping depends on the opening and the type of orifice used.

3. What are the advantages of a TLP with a TMD?

- *A spring-mass system with a higher mass ratio is effective for response reduction with a wide range of time periods.*
- *A TMD shows better control for larger wave heights.*
- *An increase in wave elevation increases the surge response at higher periods.*
- *Adding a TMD to the structure shifts the surge, heave, and pitch natural periods and increases the structure's damping ratio.*
- *The response reduction is found to be high for the higher mass ratios.*
- *Greater heave response reduction is observed due to the reduction in the surge response and the tether tension variation.*
- *By controlling the surge response, indirect control in the heave and pitch DOF is achieved.*

4. Describe the response behavior of a BLSRP under wave loads.

The deck response is significantly less than the maximum response in all active DOF. It can also be observed that the responses of the deck and buoyant legs are symmetric about the abscissa with less residue indicating high recentering capabilities. This behavior is attributed to the restraint offered by the hinged joints in both the translational and rotational DOF.

Differences in the responses of the buoyant legs are due to the variable submergence effect, which is one of the primary sources of nonlinearity in the excitation force. The presence of hinged joints at each BLS unit isolates the deck from the legs and thus improves the operational comfort and safety of the platform. The presence of rotational responses in the deck, despite the presence of hinged joints, is due to the differential heave response that occurs due to dynamic tether tension variations.

Because the buoyant legs are symmetrically spread with respect to the vertical axis of the platform, it is imperative to envisage a non-uniform phase lag in the recentering process; this causes the yaw motion of the deck. Greater stiffness in the yaw motion is due to the symmetric layout of the buoyant legs, which are spread at the bottom.

A deck response that is significantly less than that of the buoyant legs validates the use of the hinged joints; they do not transfer rotations from the legs to the deck. A lower heave response for the deck, in comparison to that of the BLS units, ensures comfortable and safe operability. The yaw response of the deck is attributed to the time delay in the recentering capability of the buoyant legs under directional wave loads.

5. Explain the continuous ice crushing phenomenon.
The major factor that limits the maximum ice force acting on any structure is the ice failure mechanism. The ice failure mechanism, in turn, depends upon ice parameters such as the ice thickness, ice velocity, width of the ice plate, and shape of the structure.

When an ice sheet interacts with a compliant structure, ice failure occurs due to ductile and brittle modes given low and high velocities, respectively. As a result, the continuous ice crushing phenomenon occurs given high ice velocity.

Ice crushing is a common ice failure mechanism of ice sheets, which results in maximum ice force on structures. It occurs when a sheet of ice hits a vertical-sided structure with moderate to high ice velocity.

During this process, horizontal cracks form on the ice sheet at the contact zone, leading to pulverization of the ice sheet. The crushed ice particles in the vicinity of the structure pile up and slide around the structure, causing the structure to vibrate.

The ice forces acting on a structure under crushing ice failure are a function of the ice strength, which depends upon the ice thickness and formation.

Continuous ice crushing during ice–structure interaction results in non-uniform, partial contact, and non-simultaneous pressure on the contact area.

The ice force–time history will have waveforms with randomly distributed wave amplitudes and periods. Thus, the ice force can be designated as a stochastic process and described using a frequency spectrum.

The uncoupled time-dependent load can be used in the dynamic analysis of structures because the transition between the different modes of failure is not completely established.

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