JEPPIAAR
ENGINEERING COLLEGE

JEPPIAAR NAGAR , RAJIV GANDHI SALAI

CHENNAI – 600 119

Department of Electronics and Communication Engineering

CEC360 – UNDERWATER NAVIGATION SYSTEMS

QUESTION BANK

Batch: (2022 – 2026)

Year/ Semester: III/VI

CEC360 UNDERWATER NAVIGATION SYSTEMS L T P C
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COURSE OBJECTIVES:

- To Understand the relationship between autonomy, sensing, navigation and control on anun-manned marine subsea vehicle.
- To understand about various types of navigational equipment & sensors
- To understand the basic communication methods and signal losses, attenuation.
- To understand the types of Acoustic transponders, Beacon and Responder

UNIT I BASICS OF UNDERWATER COMMUNICATION 9

Introduction to underwater acoustics, Understanding Thermoclines in Ocean Waters, subsea communication sensors, Instruments and applications, Sound propagation in the ocean – Sound Velocity Profiles (SVP) in the deep water and shallow water; Sound attenuation in the sea – absorption, scattering, transmission loss, reverberation, Snell's law, target strength; Laser communication and limitations.

UNIT II UNDERWATER NAVIGATION & ITS AIDING SENSOR AND DEVICES 9

Different types of navigational sensors, Accelerometers, Fiber Optic Gyroscopes (FOGs), Ring Laser Gyroscope (RLG) types and Working principles, and their applications, Doppler Velocity Log, Error sources in subsea navigation, Calibration overview for subsea navigation. Attitude Heading and Reference Systems (AHRS) & IMU

UNIT III ACOUSTIC POSITIONING SYSTEMS 9

Subsea navigation possible solutions, Vehicle positioning, Acoustic Positioning systems, Short Base Line (SBL), Super Short Base Line (SSBL), Long Base line (LBL) Configurations and Positioning overview

UNIT IV SUBSEA VEHICLE NAVIGATION 9

Subsea navigation, Uses of subsea navigation, challenges of subsea navigation. Basics of underwater navigation, Types of underwater Navigations, Aided navigational systems, Inertial Navigational systems. role of dead-reckoning navigation in subsea navigation, Kalman filters (XKF) and Invariant extended Kalman filters for navigation**.**

UNIT V CASE STUDY

Tethered vehicle deployment guidelines and preparedness.
AUV /ROV based search operation requirements and planning.
Tethered crawling vehicle sensors, data acquisition and maneuvering.
Acoustic positioning system transponder deployment and recovery
Aided and unaided navigation system study.
Understand the basic tools needed to effectively develop software for roboticplatforms in a group environment, and resolve conflicts and adhere to group goals in the software cycle.

COURSE OUTCOMES:

On successful completion of this course, the student will be able

CO1: To know about the Underwater Navigation System

CO2: To know about the INS and its aiding sensor

CO3: To know about the challenges involved in underwater navigation

CO4: To study about how navigation system is integrated with manned andunmanned underwater vehicles

CO5: To know about underwater positioning system

TOTAL:45 PERIODS

TEXT BOOKS

1. Fundamentals of ocean acoustics by L.M.Brekhovskikh and Yu. P. Lysanov
2. An Underwater Vehicle Navigation System Using Acoustic and Inertial Sensors by Norvald Kjerstad
3. Underwater Acoustic Positioning Systems by P. H. Milne

REFERENCES BOOKS

1. Electronic and Acoustic Navigation systems for Maritime Studies by Norvald Kjerstad
2. Guidance & Control of Ocean Vehicles by TT Fossen
3. Dynamic Positioning of Offshore Vessels. By Morgan, M.

CO's-PO's & PSO's MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PO1 2	PSO 1	PSO 2	PSO 3
1	3	3	3	3	2	2	-	-	-	-	-	2	3	3	3
2	3	3	2	2	**2**	2	-	-	-	-	-	2	3	2	3
3	3	3	2	2	2	2	-	-	-	-	-	2	3	2	3
4	3	3	3	2	2	1	-	-	-	-	-	2	1	2	2
5	3	3	3	2	2	2	-	-	-	-	-	3	2	1	2
CO	**3**	**3**	**3**	**2**	**2**	**2**	-	-	-	-	-	**2**	**3**	**2**	**2**

1 - low, 2 - medium, 3 - high, '-' - no correlation

Vision of the Institute	To build Jeppiaar Engineering College as an institution of academic excellence in technological and management education to become a world class University	
Mission of the Institute	**M1**	To excel in teaching and learning, research and innovation by promoting the principles of scientific analysis and creative thinking
	M2	To participate in the production, development and dissemination of knowledge and interact with national and international communities.
	M3	To equip students with values, ethics and life skills needed to enrich their lives and enable them to meaningfully contribute to the progress of society
	M4	To prepare students for higher studies and lifelong learning, enrich them with the practical and entrepreneurial skills necessary to excel as future professionals and contribute to Nation's economy
Vision of the Department	To become a centre of excellence to provide quality education and produce creative engineers in the field of Electronics and Communication Engineering to excel at international level.	
Mission of the Department	**M1**	Inculcate creative thinking and zeal for research to excel in teaching-learning process
	M2	Create and disseminate technical knowledge in collaboration with industries
	M3	Provide ethical and value based education by promoting activities for the betterment of the society
	M4	Encourage higher studies, employability skills, entrepreneurship and research to produce efficient professionals thereby adding value to the nation's economy
Program Specific Outcomes	**After the successful completion of B.E Programme in Electronics and Communication Engineering ,the graduates will be able to**	
PSO I	Design, develop and analyze electronic systems through application of relevant electronics, mathematics and engineering principles.	
PSO II	Design, develop and analyze communication systems through application of fundamentals from communication principles, signal processing, and RF System Design & Electromagnetics.	
PSO III	Adapt to emerging electronics and communication technologies and develop innovative solutions for existing and newer problems	

PEO No.	Program Educational Objectives Statements
PEO I	Produce technically competent graduates with a solid foundation in the field of Electronics and Communication Engineering with the ability to analyze, design, develop, and implement electronic systems.
PEO II	Motivate the students for successful career choices in both public and private sectors by imparting professional development activities.
PEO III	Inculcate in the students' ethical values, effective communication skills and develop the ability to integrate engineering skills to broader social needs
PEO IV	Impart professional competence, desire for lifelong learning and leadership skills in the field of Electronics and Communication Engineering

UNIT I BASICS OF UNDERWATER COMMUNICATION 9

Introduction to underwater acoustics, Understanding Thermoclines in Ocean Waters, subsea communication sensors, Instruments and applications, Sound propagation in the ocean – Sound Velocity Profiles (SVP) in the deep water and shallow water; Sound attenuation in the sea – absorption, scattering, transmission loss, reverberation, Snell's law, target strength; Laser communication and limitations.

Part A

1. **What is underwater acoustics?**
   Underwater acoustics is a branch of acoustics that focuses on the study of sound in water. It explores the behavior of sound waves underwater, considering factors such as propagation, refraction, reflection, and absorption. Applications include communication, navigation, and sensing in the underwater environment.
2. **How do thermoclines influence sound propagation in the ocean?**
   Thermoclines are layers in the ocean where there is a rapid change in temperature with depth. In underwater acoustics, thermoclines affect sound propagation by causing refraction, reflection, and absorption. The changing temperature in thermoclines leads to variations in the speed of sound, impacting the trajectory of sound waves and influencing their behavior in the underwater environment.
3. **Why is the speed of sound important in underwater acoustics, and how is it affected by thermoclines?**
   The speed of sound is crucial in underwater acoustics because it determines how quickly sound waves travel through water. Thermoclines influence the speed of sound by creating temperature gradients. In areas with thermoclines, sound waves experience varying speeds due to temperature changes, leading to refraction, reflection, and changes in their paths through the water.
4. **Explain the concept of refraction in underwater acoustics.**
   Refraction in underwater acoustics refers to the bending of sound waves as they pass through regions with different sound speeds. Thermoclines, where temperature changes rapidly, contribute to refraction. Sound waves tend to bend towards areas of lower sound speed, causing them to follow curved paths. This phenomenon is essential for understanding and predicting the trajectory of sound waves in the ocean.
5. **What are subsea communication sensors?**
   Subsea communication sensors are devices designed for transmitting and receiving data in underwater environments. These sensors facilitate communication between submerged equipment, vehicles, or instruments. They play a crucial role in underwater monitoring, data collection, and control of subsea systems.
6. **Why are subsea communication sensors essential in underwater applications?**
   Subsea communication sensors are essential in underwater applications because they enable real-time data exchange and control between submerged devices. These sensors facilitate communication in challenging underwater conditions, allowing for tasks such as remote sensing, monitoring of oceanographic parameters, and coordination between autonomous underwater vehicles (AUVs) and other subsea equipment.
7. **What challenges do subsea communication sensors address in underwater environments?**
   Subsea communication sensors address challenges such as signal attenuation, limited bandwidth, and the impact of environmental factors like temperature and pressure. They are designed to operate reliably in the harsh underwater conditions, allowing for efficient and secure data transmission in applications such as offshore exploration, environmental monitoring, and subsea infrastructure maintenance.
8. **How do subsea communication sensors contribute to the development of underwater technologies?**
   Subsea communication sensors contribute to the development of underwater technologies by enabling seamless communication between underwater devices. This fosters advancements in autonomous underwater vehicles (AUVs), remotely operated vehicles (ROVs), and underwater sensor networks. These

sensors play a vital role in enhancing the capabilities of subsea systems, leading to improved efficiency, data collection, and exploration in underwater environments.

9. **What are some instruments used for studying sound propagation in the ocean? (2 marks)**
   Hydrophones are commonly used instruments for studying sound propagation in the ocean. These underwater microphones are designed to detect and record underwater sounds. Additionally, acoustic doppler current profilers (ADCPs) are employed to measure ocean currents by analyzing sound reflections off moving particles in the water.
10. **How is sound propagation in the ocean utilized for navigation?**
    Sound propagation in the ocean is utilized for underwater navigation through the use of sonar systems. Sonar (Sound Navigation and Ranging) technology emits sound waves and measures their reflections to determine the distance and location of underwater objects. This application is crucial for navigation, submarine tracking, and underwater mapping.
11. **Explain the role of sound propagation studies in marine biology.**
    Sound propagation studies in the ocean are essential in marine biology for understanding marine animal behavior and communication. Hydrophones are deployed to record and analyze the sounds produced by marine organisms, such as whales and dolphins. This information aids researchers in studying migration patterns, mating rituals, and overall ecological dynamics.

12. **How do oceanographers use sound propagation data for studying the ocean environment?**
    Oceanographers use sound propagation data to study the ocean environment by analyzing how sound waves travel through water. This information helps in mapping the ocean floor, determining temperature and salinity profiles, and studying underwater geophysical processes. Acoustic tomography is one technique that utilizes sound propagation to measure ocean properties over large distances.
13. **Name a technology that exploits sound propagation for long-range communication in the ocean.**
    Underwater Acoustic Modems are technologies that exploit sound propagation for long-range communication in the ocean. These modems use acoustic signals to transmit data between underwater instruments, vehicles, and surface platforms, making them valuable for oceanographic research, environmental monitoring, and offshore industries.
14. **Explain the significance of Sound Velocity Profiles (SVP) in deep water. (2 marks)**
    Sound Velocity Profiles (SVP) in deep water are crucial for understanding the variations in sound speed with depth. These profiles help in predicting sound propagation, refraction, and the behavior of underwater acoustics. In deep water, SVP is essential for accurate sonar performance, navigation, and communication systems.

15. **How does Sound Velocity Profiles (SVP) differ in shallow water compared to deep water? (2 marks)**
    In shallow water, Sound Velocity Profiles exhibit more variability due to factors like temperature gradients near the surface and interactions with the seabed. Shallow water SVPs have a significant impact on sound propagation, causing increased signal loss, reflections, and refraction, making underwater acoustics more complex.

16. **Briefly describe the components of sound attenuation in the sea. (2 marks)**
    Sound attenuation in the sea involves absorption, scattering, transmission loss, reverberation, and other factors. Absorption is the conversion of sound energy into heat, scattering is the redirection of sound waves by particles, transmission loss is the reduction in sound intensity with distance, and reverberation is the persistence of sound due to multiple reflections.

17. **Explain Snell's Law in the context of sound propagation. (2 marks)**
    Snell's Law describes how sound waves refract when they pass through layers with different sound speeds. It states that the angle of incidence and the angle of refraction are related to the ratio of sound speeds in the two media. In underwater acoustics, Snell's Law is fundamental for predicting the trajectory of sound waves as they pass through layers with varying sound velocities.

18. **Define target strength in the context of underwater acoustics. (2 marks)**
    Target strength refers to the ability of an object or a target to reflect or scatter sound waves. In underwater acoustics, understanding target strength is crucial for detecting and identifying objects using sonar systems. It depends on the target's size, shape, and composition.

19. **What is laser communication, and how is it applied underwater? (2 marks)**
    Laser communication involves using laser beams to transmit data. Underwater, laser communication can be applied by using modulated lasers to transmit information through water. This technology is used for short-range, high-bandwidth communication in underwater environments.

20. **State one limitation of laser communication in underwater applications. (2 marks)**
    A significant limitation of laser communication underwater is the rapid attenuation of light in water due to absorption and scattering. As water absorbs and scatters light quickly, the effective range of laser communication in underwater environments is limited, making it suitable mainly for short-distance applications.

21. **How does absorption affect laser communication in underwater environments? (2 marks)**
    Absorption is a major limitation in underwater laser communication. Water absorbs light at various wavelengths, especially in the blue and green regions of the spectrum. This absorption results in a rapid decrease in the intensity of the laser beam with distance, limiting the effective range of laser communication in the underwater domain.

22. **Briefly explain the concept of scattering in laser communication underwater. (2 marks)**
    Scattering in laser communication refers to the redirection of light due to interactions with particles or impurities in the water. Scattering causes the laser beam to deviate from its intended path, leading to signal loss and reduced communication effectiveness. Minimizing scattering is a challenge in designing reliable underwater laser communication systems.

23. **State one application where laser communication in underwater environments might be preferred despite its limitations.**
    One application where laser communication in underwater environments might be preferred is in short-range, high-bandwidth communication for underwater vehicles, sensors, or instruments operating in close proximity. Despite limitations, the high data transfer rates offered by laser communication can be advantageous in specific scenarios where distance is not a critical factor.
24. **Explain the concept of transmission loss in underwater acoustics. (2 marks)**
    Transmission loss in underwater acoustics refers to the reduction in sound intensity as it travels through the water. This loss occurs due to factors such as absorption, scattering, and geometric spreading. Transmission loss is a critical consideration in designing underwater communication and sonar systems as it affects the effective range and clarity of transmitted signals.

25. **Define reverberation in the context of underwater acoustics. (2 marks**
    Reverberation in underwater acoustics is the persistence of sound due to multiple reflections off surfaces and objects in the water. It creates a complex acoustic environment, making it challenging to distinguish between the original sound and its reflections. Managing reverberation is essential for improving the accuracy and reliability of underwater acoustic systems.

26. **How does Snell's Law influence sound propagation near the ocean surface? (2 marks)**
    Snell's Law influences sound propagation near the ocean surface by determining the angle at which sound waves refract as they pass through the interface between water and air. The variation in sound speed near the surface can lead to significant refraction, affecting the trajectory of sound waves and complicating underwater communication and navigation in shallow water environments.

27. **Why is understanding target strength important in sonar applications? (2 marks)**
    Understanding target strength is crucial in sonar applications because it helps in detecting and identifying underwater objects. The target strength depends on the object's acoustic characteristics, and analyzing this information aids in determining the size, shape, and composition of the target, enhancing the effectiveness of sonar systems for naval, research, and environmental monitoring purposes.

28. **Give an example of an instrument used for measuring sound velocity profiles in the ocean. (2 marks)**
    CTD (Conductivity, Temperature, and Depth) sensors are commonly used instruments for measuring sound velocity profiles in the ocean. These sensors provide information on temperature and salinity, which are crucial for determining the speed of sound in water and creating accurate sound velocity profiles for underwater acoustics studies.

PART B &C

1. **Explain briefly about underwater acoustics system**
2. **Describe about Thermoclines in Ocean Waters**
3. **List the subsea communication sensors and explain in detail.**
4. **Short notes on each Instruments used in underwater acoustics system**
5. **State the limitations of laser communication in underwater applications**
6. **Explain briefly about Sound propagation in the ocean**
7. **Sound Velocity Profiles (SVP) in the deep water and shallow water**
8. **Explain short notes on each Sound attenuation in the sea – absorption, scattering, transmission loss, reverberation**
9. **List and explain the sound attenuation in the sea.**
10. **Explain Snell's Law in the context of sound propagation**
11. **Explain about target strength;**
12. **Give detail about Laser communication and limitations.**

UNIT II UNDERWATER NAVIGATION & ITS AIDING SENSOR AND DEVICES 9

Different types of navigational sensors, Accelerometers, Fiber Optic Gyroscopes (FOGs), Ring Laser Gyroscope (RLG) types and Working principles, and their applications, Doppler Velocity Log, Error sources in subsea navigation, Calibration overview for subsea navigation. Attitude Heading and Reference Systems (AHRS) & IMU

PART - A

1. **Name two types of navigational sensors used in maritime applications. (2 marks)**
   Two types of navigational sensors used in maritime applications are GPS (Global Positioning System) receivers and Inertial Navigation Systems (INS).

2. **Briefly explain the working principle of a GPS receiver. (2 marks)**
   GPS receivers determine position by receiving signals from satellites in Earth's orbit. These receivers calculate the distance to multiple satellites using the time delay of signals, and by triangulating these distances, they determine the user's precise location.

3. **What is the primary function of an accelerometer in navigation? (2 marks)**
   Accelerometers measure the rate of change of velocity (acceleration) of a moving object. In navigation, accelerometers are used to determine changes in the speed and direction of a vessel, providing data for dead reckoning and aiding in maintaining accurate positioning.

4. **Compare Fiber Optic Gyroscopes (FOGs) and Ring Laser Gyroscopes (RLG) in terms of their working principles. (2 marks)**
   Both FOGs and RLGs are based on the Sagnac effect, where the rotation of a closed-loop interferometer affects the phase of light beams. FOGs use a coil of optical fiber, while RLGs use a closed loop of laser beams. Both systems measure rotation rates accurately.

5. **Provide an application for Fiber Optic Gyroscopes (FOGs) in maritime navigation. (2 marks)**
   Fiber Optic Gyroscopes (FOGs) are commonly used in maritime navigation for ship stabilization systems. They help in maintaining vessel stability by providing precise information about the ship's motion.

6. **What is the primary function of a Doppler Velocity Log (DVL) in underwater navigation? (2 marks)**
   Doppler Velocity Logs (DVLs) measure a vessel's velocity relative to the seafloor by analyzing the Doppler shift of acoustic signals. This information is crucial for underwater navigation, especially in scenarios where GPS signals are not available.

7. **Name one common source of error in subsea navigation systems. (2 marks)**
   One common source of error in subsea navigation is acoustic signal propagation variability, which can lead to inaccuracies in determining the distance between the transducer and the seafloor.

8. **Why is calibration important in subsea navigation systems? (2 marks)**
   Calibration is crucial in subsea navigation to ensure the accuracy and reliability of sensor measurements. It corrects for systematic errors and variations, providing precise data for navigation and positioning in underwater environments.

9. **What is the main function of an Inertial Measurement Unit (IMU) in marine navigation? (2 marks)**

The main function of an Inertial Measurement Unit (IMU) in marine navigation is to measure and provide accurate information about a vessel's acceleration, angular rate, and sometimes magnetic field strength. This data is used for navigation, stabilization, and control purposes.

10. **Explain the role of an Attitude Heading and Reference System (AHRS) in marine applications. (2 marks)**
    Attitude Heading and Reference Systems (AHRS) provide real-time information about a vessel's orientation (pitch, roll, and yaw) and heading. AHRS combines data from various sensors like accelerometers, gyroscopes, and magnetometers to deliver accurate and stable information for navigation and control systems.

11. **Provide an example of a practical application for Inertial Measurement Units (IMUs) in maritime operations. (2 marks)**
    In maritime operations, Inertial Measurement Units (IMUs) are often used in dynamic positioning systems for ships. IMUs provide real-time data on the vessel's acceleration, allowing for precise control and stabilization, especially in challenging sea conditions.

12. **Name one source of error in Inertial Measurement Units (IMUs) and how it can be mitigated. (2 marks)**
    Gyroscopic drift is a common source of error in IMUs. This drift can be mitigated through calibration processes, including periodic realignment with external references or employing sophisticated algorithms that compensate for the drift over time.

13. **How does a Ring Laser Gyroscope (RLG) work in the context of marine navigation? (2 marks)**
    In marine navigation, a Ring Laser Gyroscope (RLG) measures the rotation rate of a vessel by utilizing the Sagnac effect. As the vessel rotates, the interference pattern of laser beams in the closed loop changes, and this change is proportional to the vessel's angular velocity, providing accurate information for navigation and heading control.

14. **What role does Doppler Velocity Log (DVL) play in autonomous underwater vehicles (AUVs)? (2 marks)**
    Doppler Velocity Logs (DVLs) are crucial for autonomous underwater vehicles (AUVs) as they provide real-time information about the vehicle's velocity relative to the seafloor. This data helps AUVs maintain their desired trajectory, avoid obstacles, and execute precise underwater missions.

15. **Why is the accuracy of navigational sensors particularly important in subsea environments? (2 marks)**
    The accuracy of navigational sensors is crucial in subsea environments because the lack of visual references and limited access to GPS signals make underwater navigation challenging. Precise data from sensors ensures accurate positioning, navigation, and control of subsea vehicles and instruments in these complex and often remote environments.

16. **Outline the principles of DVL .**
    DVL operates based on the Doppler Effect, which is the change in frequency or wavelength of a wave in relation to an observer moving relative to the source of the wave. In the context of a DVL, acoustic signals (usually sound waves) are emitted from the device and directed towards the seabed.

17. **List the Applications of DVL**
    Doppler Velocity Logs are commonly used in navigation for underwater vehicles, submarines, and surface vessels.
    They provide accurate and real-time information about the speed and direction of a vessel with respect to the seabed, which is crucial for navigation, position fixing, and maintaining a desired course.
18. **List the types of RLG**
    Single-Mode Ring Laser Gyroscope
    Multi-Mode Ring Laser Gyroscope
19. **Define single-Mode Ring Laser Gyroscope:**
    In a single-mode RLG, a single longitudinal mode of the laser oscillation is used.
    It typically has a single closed loop or ring in which the laser beams circulate.
    The interference pattern generated by the laser beams is used to detect any changes in the gyroscope's orientation
20. **Define Multi-Mode Ring Laser Gyroscope**
    In a multi-mode RLG, multiple longitudinal modes of the laser oscillation are employed.
    This type of RLG usually has multiple closed loops or rings for the laser beams to circulate.
    The interference patterns from multiple modes are analyzed to determine changes in orientation.

PART B & C

1. **List the Different types of navigational sensors and explain briefly.**
2. **Summarize the working principle, construction, and applications of Accelerometers.**
3. **Summarize the working principle, construction, and applications of Fiber Optic Gyroscopes (FOGs).**
4. **With neat diagram explain Ring Laser Gyroscope (RLG) types and Working principles, and their applications.**
5. **Explain the principle and working of Doppler Velocity Log.**
6. **Detail about Errors in a Doppler log & how are some of these errors overcome by the Janus Configuration.**
7. **Explain about Error sources in subsea navigation.**
8. **Give detail about Calibration overview for subsea navigation.**
9. **With neat diagram, explain the Attitude Heading and Reference Systems (AHRS) & IMU.**
10. **Interpret about IMU.**

UNIT III ACOUSTIC POSITIONING SYSTEMS 9

Subsea navigation possible solutions, Vehicle positioning, Acoustic Positioning systems, Short Base Line (SBL), Super Short Base Line (SSBL), Long Base line (LBL) Configurations and Positioning overview

PART A

1. **What are the primary challenges in subsea navigation, and how are they addressed by possible solutions? (2 marks)**
   Subsea navigation faces challenges such as limited visibility, lack of GPS signals, and acoustic signal variability. Possible solutions include acoustic positioning systems, which utilize sound waves for precise positioning, allowing vehicles and instruments to navigate accurately in underwater environments.

2. **Why is accurate vehicle positioning essential in subsea operations? (2 marks)**
   Accurate vehicle positioning in subsea operations is crucial for tasks like underwater exploration, pipeline inspection, and resource extraction. Precise positioning enables efficient and safe maneuvering of subsea vehicles, ensuring they reach their intended locations with precision.

3. **What is the primary principle behind acoustic positioning systems? (2 marks)**
   Acoustic positioning systems use sound waves to determine the position of underwater vehicles or instruments. By measuring the time it takes for acoustic signals to travel between transponders and receivers, these systems calculate distances and provide accurate positioning information.

4. **Briefly explain the Short Base Line (SBL) configuration in acoustic positioning. (2 marks)**
   Short Base Line (SBL) configuration in acoustic positioning involves placing transponders (signal emitters) on the seabed, and a surface vessel or subsea vehicle equipped with a receiver. The system calculates positions based on the relatively short distances between the transponders and the receiver.

5. **How does the Super Short Base Line (SSBL) configuration differ from Short Base Line (SBL) in acoustic positioning? (2 marks)**
   In Super Short Base Line (SSBL) configuration, the distances between transponders and the receiver are even shorter than in SBL. This configuration offers higher precision in positioning, making it suitable for applications where extreme accuracy is required, such as in underwater construction projects.

6. **Describe the Long Base Line (LBL) configuration in acoustic positioning. (2 marks)**
   Long Base Line (LBL) configuration involves placing multiple transponders at known locations across a large area. The distances between the transponders and the receiver are relatively long. The system calculates the position of the receiver by triangulating the distances from multiple transponders.

7. **Why is a positioning overview essential in acoustic systems for subsea navigation? (2 marks)**
   A positioning overview is essential in acoustic systems for subsea navigation to provide a comprehensive understanding of the vehicle's or instrument's location. This overview ensures accurate positioning, aids in navigation, and allows operators to monitor and control subsea activities effectively.

8. **Provide an application scenario where Short Base Line (SBL) acoustic positioning might be preferred. (2 marks)**

Short Base Line (SBL) acoustic positioning is suitable for applications such as underwater inspections, where precise location information is required in relatively confined areas. It is commonly used in scenarios where a surface vessel or subsea vehicle can access the seabed easily.

9. **How does the choice between Short Base Line (SBL) and Long Base Line (LBL) configurations depend on the operational requirements? (2 marks)**
   The choice between SBL and LBL configurations depends on the operational requirements. SBL is suitable for short-range, high-precision applications, while LBL is preferred for larger areas where accurate positioning over longer distances is necessary, such as in offshore drilling or geological surveys.

10. **Explain the role of acoustic positioning systems in supporting underwater construction projects.**
    Acoustic positioning systems play a critical role in supporting underwater construction projects by providing accurate location information for subsea vehicles and equipment. This ensures precise placement of structures, such as pipelines or subsea installations, contributing to the success and safety of the construction activities.

11. **In what scenarios might Super Short Base Line (SSBL) configurations be advantageous over other acoustic positioning systems? (2 marks)**
    Super Short Base Line (SSBL) configurations are advantageous in scenarios where extremely high positioning accuracy is crucial, such as in tasks requiring precision maneuvering or detailed inspections in confined spaces. Examples include intricate operations in underwater archaeology or maintenance tasks on underwater infrastructure.

12. **Describe one limitation of acoustic positioning systems and suggest a mitigation strategy. (2 marks)**
    One limitation of acoustic positioning systems is the potential for signal reflections and multipath interference, especially in areas with complex underwater structures. To mitigate this, advanced signal processing algorithms and careful placement of transponders can be employed to minimize the impact of reflections and enhance the accuracy of the positioning system.

13. **How does the choice of acoustic positioning configuration impact the cost of implementing a subsea navigation system? (2 marks)**
    The choice of acoustic positioning configuration can impact the cost of implementing a subsea navigation system. Short Base Line (SBL) configurations are generally more cost-effective for short-range applications, while Long Base Line (LBL) configurations, requiring more transponders and infrastructure, may incur higher costs but offer advantages in terms of coverage and accuracy over larger areas.

14. **Provide an example of an industry where acoustic positioning systems are extensively utilized.**
    Acoustic positioning systems are extensively utilized in the offshore oil and gas industry. They play a critical role in positioning and monitoring subsea infrastructure, including pipelines, drilling rigs, and underwater installations, ensuring precise and efficient operations in challenging marine environments.

15. **How does acoustic positioning contribute to the overall efficiency of autonomous underwater vehicles (AUVs)? (2 marks)**
    Acoustic positioning enhances the efficiency of Autonomous Underwater Vehicles (AUVs) by providing real-time and accurate location data. This allows AUVs to navigate autonomously, execute predefined missions, and adapt to changes in their environment, contributing to improved operational efficiency and successful completion of underwater tasks.

16. **Describe the impact of acoustic signal variability on the performance of acoustic positioning systems.**
    Acoustic signal variability, influenced by factors like water temperature, salinity, and pressure, can impact the accuracy of acoustic positioning systems. Variations in sound speed affect the travel time of acoustic signals, introducing errors in distance calculations. Advanced algorithms and environmental compensation techniques are employed to mitigate the impact of signal variability on system performance.

17. **How does the deployment of acoustic positioning systems contribute to the safety of underwater activities? (2 marks)**
    The deployment of acoustic positioning systems enhances the safety of underwater activities by providing accurate and real-time information about the location of subsea assets. This ensures precise navigation, reducing the risk of collisions or incidents, and enables efficient monitoring of underwater operations, enhancing overall safety in subsea environments.

18. **Briefly explain the concept of triangulation and its relevance in Long Base Line (LBL) configurations.**
    Triangulation involves determining a position by measuring distances from multiple known points. In Long Base Line (LBL) configurations, triangulation is applied by using multiple transponders at known locations to calculate the position of a receiver. This method provides accurate positioning information over larger areas.

19. **In what types of underwater projects would the Super Short Base Line (SSBL) configuration be particularly advantageous? (2 marks)**
    The Super Short Base Line (SSBL) configuration is particularly advantageous in underwater projects that require high precision in a small and confined space. Examples include tasks like underwater inspections of delicate structures, intricate maintenance operations, or scientific studies where extremely accurate positioning is critical.

20. **Explain how acoustic positioning systems contribute to the efficiency of underwater research and exploration. (2 marks)**
    Acoustic positioning systems contribute to the efficiency of underwater research and exploration by providing precise location information for research vessels, remotely operated vehicles (ROVs), and autonomous underwater vehicles (AUVs). This accuracy allows scientists to target specific underwater features, conduct detailed studies, and efficiently explore diverse marine environments, supporting scientific discovery and environmental monitoring efforts.

PART B & C

1. **List the Subsea navigation possible solutions with detail.**
2. **Summarize the working principle of Vehicle positioning.**
3. **Interpret the Acoustic Positioning systems**
4. **Explain the operation and performance of a short baseline (SBL) acoustic positioning system**
5. **Explain the operation and performance of a Long Base line (LBL)**
6. **Analyze the Configurations and Positioning overview**
7. **Briefly explain the different classes of acoustic positioning system.**

UNIT IV SUBSEA VEHICLE NAVIGATION 9

Subsea navigation, Uses of subsea navigation, challenges of subsea navigation. Basics of underwater navigation, Types of underwater Navigations, Aided navigational systems, Inertial Navigational systems. role of dead-reckoning navigation in subsea navigation, Kalman filters (XKF) and Invariant extended Kalman filters for navigation**.**

Part A

1. **Define subsea navigation. (2 marks)**
   Subsea navigation involves the process of determining and maintaining the position of underwater vehicles, instruments, or structures in the underwater environment.

2. **Why is subsea navigation challenging compared to surface navigation? (2 marks)**
   Subsea navigation is challenging due to limited visibility, lack of GPS signals, acoustic signal variability, and the complex nature of the underwater environment.

3. **Provide one practical application of subsea navigation. (2 marks)**
   One practical application of subsea navigation is in the offshore oil and gas industry for the precise positioning of underwater equipment during exploration, drilling, and maintenance operations.

4. **How does subsea navigation contribute to underwater research? (2 marks)**
   Subsea navigation supports underwater research by providing accurate positioning for research vessels and instruments, enabling scientists to conduct targeted studies, explore specific underwater features, and monitor marine environments effectively.

5. **Name one major challenge in subsea navigation and suggest a solution. (2 marks)**
   Limited visibility is a challenge. One solution is the use of acoustic positioning systems that rely on sound waves to determine underwater positions accurately.

6. **Why is the lack of GPS signals a significant challenge in subsea navigation? (2 marks)**
   The lack of GPS signals underwater limits the use of traditional navigation methods. Acoustic, inertial, and aided navigational systems are often employed as alternatives.

7. **Define dead reckoning navigation. (2 marks)**
   Dead reckoning navigation involves estimating the current position of a vessel or vehicle based on a previously known position, taking into account the course, speed, and time elapsed.

8. **Why is underwater navigation more complex than surface navigation? (2 marks)**
   Underwater navigation is more complex due to factors such as water currents, acoustic signal variability, limited visibility, and the absence of reliable surface references.

9. **Name two types of underwater navigation methods. (2 marks)**
   Two types of underwater navigation methods are acoustic navigation and inertial navigation.

10. **How does aided navigation enhance underwater positioning accuracy? (2 marks)**

Aided navigation combines multiple sensors and external references, such as acoustic transponders, to improve the accuracy of underwater positioning systems.

11. **Define Inertial Navigation Systems (INS). (2 marks)**
    Inertial Navigation Systems (INS) use accelerometers and gyroscopes to continuously calculate changes in position, providing autonomous navigation capabilities.

12. **How do Inertial Navigation Systems compensate for the lack of external references? (2 marks)**
    Inertial Navigation Systems rely on internal sensors, such as accelerometers and gyroscopes, to measure changes in velocity and direction, allowing navigation without external references.

13. **Explain the role of dead reckoning in subsea navigation. (2 marks)**
    Dead reckoning is used in subsea navigation to estimate a vehicle's position by continuously updating its previous known position based on the integrated effects of course, speed, and time.

14. **Name one limitation of dead reckoning navigation and suggest a mitigation strategy. (2 marks)**
    Dead reckoning is prone to cumulative errors over time. A mitigation strategy is to periodically update the dead reckoning position with more accurate external references, such as acoustic fixes.

15. **Briefly explain the role of Kalman filters (XKF) in underwater navigation. (2 marks)**
    Kalman filters are used in underwater navigation to estimate the true state of a system by continuously integrating sensor measurements and predicting future states while considering measurement uncertainties.

16. **What is the advantage of using Invariant Extended Kalman Filters in navigation? (2 marks)**
    Invariant Extended Kalman Filters provide improved performance in the presence of non-linearities, making them suitable for navigation systems where sensor measurements are subject to complex underwater conditions.

17. **How does Kalman filtering contribute to improving the accuracy of sensor measurements in subsea navigation? (2 marks)**
    Kalman filtering enhances the accuracy of sensor measurements in subsea navigation by dynamically adjusting the weighting of measurements and predictions. It minimizes errors by considering both the uncertainty in sensor readings and the system dynamics.

18. **Provide an example scenario where Invariant Extended Kalman Filters could be advantageous for underwater navigation. (2 marks)**

    Invariant Extended Kalman Filters could be advantageous in underwater navigation scenarios where the navigation system encounters significant non-linearities, such as navigating through complex underwater terrain or in the presence of strong currents.

19. **How do Kalman filters contribute to mitigating errors in dead reckoning navigation? (2 marks)**
    Kalman filters contribute to mitigating errors in dead reckoning navigation by continuously updating the estimated position based on sensor measurements while considering the inherent uncertainties. This adaptive filtering helps reduce cumulative errors over time.

20. **Explain the concept of sensor fusion in the context of aided navigational systems. (2 marks)**

Sensor fusion involves integrating data from multiple sensors, such as acoustic transponders, inertial sensors, and external references, to obtain a more accurate and reliable estimation of the underwater vehicle's or instrument's position. This enhances the overall performance of aided navigational systems.

PART B & C

1. **Explain briefly about Subsea navigation,**
2. **List and explain the Uses of subsea navigation,**
3. **Summarize the challenges of subsea navigation.**
4. **Brief notes on Basics of underwater navigation,**
5. **Summarize the Types of underwater Navigations,**
6. **Discuss briefly about Aided navigational systems,**
7. **Interpret the Inertial Navigational systems.**
8. **Express the role of dead-reckoning navigation in subsea navigation,**
9. **Describe the Kalman filters (XKF)**
10. **Explain briefly about Invariant extended Kalman filters for navigation.**

UNIT V CASE STUDY

Tethered vehicle deployment guidelines and preparedness.
AUV /ROV based search operation requirements and planning.
Tethered crawling vehicle sensors, data acquisition and maneuvering.
Acoustic positioning system transponder deployment and recovery
Aided and unaided navigation system study.
Understand the basic tools needed to effectively develop software for robotic platforms in a group environment, and resolve conflicts and adhere to group goals in the software cycle.

1. **Name one key consideration in the deployment of tethered vehicles. (2 marks)**
   One key consideration in tethered vehicle deployment is ensuring proper cable management to prevent entanglement and ensure smooth operation.

2. **Why is pre-deployment testing crucial for tethered vehicles? (2 marks)**
   Pre-deployment testing is crucial for tethered vehicles to identify and rectify any equipment issues, verify communication links, and ensure the overall readiness of the system for the intended mission.

3. **Provide one requirement for an effective AUV/ROV search operation. (2 marks)**
   An effective AUV/ROV search operation requires a detailed mission plan, specifying the search area, depth, and objectives.

4. **Why is accurate mapping essential in AUV/ROV search operations? (2 marks)**
   Accurate mapping is essential in AUV/ROV search operations to navigate the vehicles efficiently, identify search areas, and locate targets or points of interest.

5. **Name one type of sensor commonly used on tethered crawling vehicles. (2 marks)**
   Cameras are commonly used sensors on tethered crawling vehicles for visual inspection and data acquisition.

6. **Why is real-time data acquisition critical for tethered crawling vehicles? (2 marks)**
   Real-time data acquisition is critical for tethered crawling vehicles to enable operators to make informed decisions, respond to changing conditions, and ensure the success of the mission.

7. **Explain the purpose of acoustic positioning system transponders. (2 marks)**
   Acoustic positioning system transponders help in accurately determining the position of underwater vehicles by emitting acoustic signals that are detected by receivers, enabling precise navigation.

8. **Why is proper deployment and recovery of transponders important? (2 marks)**
   Proper deployment and recovery of transponders are important to ensure the accuracy and reliability of the acoustic positioning system. Misplacement or damage can impact navigation precision.

9. **Differentiate between aided and unaided navigation systems. (2 marks)**
   Aided navigation systems use external references or sensors (e.g., GPS, acoustic transponders), while unaided navigation relies solely on onboard sensors (e.g., inertial sensors) without external assistance.

10. **Provide one advantage of aided navigation systems over unaided systems. (2 marks)**
    Aided navigation systems typically offer higher accuracy and reliability, especially in challenging environments, due to the additional information provided by external references.

11. **Name one basic tool needed to develop software for robotic platforms. (2 marks)**
    Integrated Development Environments (IDEs) are basic tools needed to develop software for robotic platforms, providing a comprehensive environment for coding, debugging, and testing.

12. **How does effective group collaboration contribute to successful software development for robotic platforms? (2 marks)**
    Effective group collaboration ensures that diverse skills are utilized, tasks are efficiently distributed, and conflicts are resolved, leading to the achievement of group goals in the software development cycle.

13. **Why is conflict resolution important in a group working on software development for robotic platforms? (2 marks)**
    Conflict resolution is crucial in maintaining a positive working environment and ensuring that disagreements or differences within the group do not hinder the progress of software development. It promotes effective communication and collaboration.

14. **Provide an example of a collaborative software development tool for robotic platforms. (2 marks)**
    Version control systems, such as Git, are collaborative tools widely used in software development for robotic platforms. They enable multiple team members to work on the same codebase concurrently and manage changes effectively.

15. **How does adherence to group goals contribute to successful software development? (2 marks)**
    Adherence to group goals ensures that individual efforts align with the overall objectives of the software development project, promoting unity, efficiency, and the successful completion of tasks.

16. **Name one conflict resolution strategy that can be applied in a group working on software development. (2 marks)**
    Open communication and active listening are essential conflict resolution strategies. By fostering an environment where team members can express concerns and ideas openly, conflicts can be addressed collaboratively.

PART B & C

1. **Discuss about Tethered vehicle deployment guidelines and preparedness.**
2. **Give details of AUV /ROV based search operation requirements and planning.**
3. **Describe the Tethered crawling vehicle sensors, data acquisition and maneuvering.**
4. **Interpret the Acoustic positioning system transponder deployment and recovery**
5. **Summarize the Aided and unaided navigation system study.**
6. **List and detail about the basic tools needed to effectively develop software for robotic platforms in a group environment**
7. **Analyze how to resolve conflicts and adhere to group goals in the software cycle.**