KUMARAGURU college of technology
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Register Number:……

M.TECH DEGREE EXAMINATIONS: NOV/DEC 2024

(Regulation 2018)

First Semester

DEFENCE TECHNOLOGY

P18DTE0006**:** Autonomy and Navigation Technology

COURSE OUTCOMES

CO1: Describe the basic principle of operation of inertial navigation system and derive the inertial navigation equations.

CO2: Explain the operation of inertial sensors.

CO3: Describe the basic principle of operation of a global navigation satellite system and solve the equations for calculating a position estimate from a given satellite constellation.

CO4: Explain the integrated navigation techniques and guidance laws for autonomous vehicles.

CO5: Carry out the path planning for UGV/UAV.

Time: Three Hours **Maximum Marks: 100**

Answer all the Questions:-

PART A (10 x 1 = 10 Marks)

1. Identify the correct sequence of steps in the process of computing the position and velocity in inertial navigation algorithm: CO1 [K_2]
   1. Integration process
   2. Acceleration measurements in navigation frame
   3. Acceleration measurements in body frame
   4. Attitude computation

   a) 2-3-1-4 b) 2-3-4-1
   c) 3-4-2-1 d) 3-2-1-4

2. The raw output of global positioning system (GPS) is CO3 [K_1]
   a) Position b) Velocity
   c) Time d) Pseudo range

3. The raw output of an accelerometer is CO2 [K_1]
   a) Linear acceleration b) Angular acceleration
   c) Specific force d) Angular rate

4. Match the given geodetic coordinates in List I with the corresponding xyz position in CO3 [K_2]

the ECEF frame given in List II.

List I	List II
(A) Latitude = 0º, Longitude = 0º, Height = 0 meters	(i) x = 0 km, y = 6378 km, z = 0 km
(B) Latitude = 0º, Longitude = 90º, Height = 0 meters	(ii) x = 0 km, y = 0 km, z = 6356 km
(C) Latitude = 90º, Longitude = 0º, Height = 0 meters	(iii) x = 6378 km, y = 0 km, z = 0 km

a) (A)-(ii), (B)-(iii), (C)-(i)
b) (A)-(iii), (B)-(i), (C)-(ii)
c) (A)-(ii), (B)-(i), (C)-(iii)
d) (A)-(iii), (B)-(ii), (C)-(i)

5. In PN guidance, the PN constant for which a missile is turning faster than the LOS is _____. CO4 [K_2]

a) 0.3
b) 0.707
c) 1
d) 4

6. Which one of the following sensors measures the angular rates of rotation of a vehicle about its roll, pitch, and yaw axes? CO2 [K_1]

a) Rate gyros
b) Rate integrating gyros
c) Linear accelerometers
d) Rotary encoders

7. Assertion (A): Inertial navigation systems are self-contained. CO1 [K_2]
Reason (R): Position errors are accumulated in inertial navigation systems.

a) Both A and R are Individually true and R is the correct explanation of A
b) Both A and R are Individually true but R is not the correct explanation of A
c) A is true but R is false
d) A is false but R is true

8. Consider a GPS navigation message with 20 frames. What is the total number of words in the message? CO3 [K_2]

a) 500
b) 1000
c) 1500
d) 2000

9. Which of the following are the steps involved in the path planning process for autonomous vehicles? CO5 [K_2]

(i) Determination of waypoints.
(ii) Generation of a path based on the waypoints.
(iii) Computing the desired position and velocity of the vehicle.
(iv) Determining the control forces and moments for the vehicle.

a) (i) and (ii) only
b) (i), (ii) and (iii) only

c) (iii) and (iv) only d) (ii) and (iv) only

10. Which one of the following is essential for a Kalman filter to estimate the states of a dynamic system? CO4 [K1]

a) Kalman parameter b) Kalman constant

c) Kalman gain d) Kalman feedback

PART B (10 x 2 = 20 Marks)

11. Why is an inertial navigation system called "autonomous"? CO1 [K2]

12. Draw the following coordinate systems (frames) with clear indication of their axes: CO1 [K2]
(i) Inertial frame, (ii) ECEF frame.

13. Why the range measurement in GPS is termed as **pseudorange**? CO3 [K2]

14. What is the principle of dead reckoning navigation? CO1 [K2]

15. What is the main advantage of a stable platform inertial navigation system (INS) over the strapdown system, and what is the major drawback of a stable platform INS? CO1 [K2]

16. What is Coriolis acceleration for a vehicle? CO2 [K2]

17. Show the relationship between the guidance, navigation, and control systems for an autonomous unmanned aerial vehicle. CO4 [K2]

18. What is **path planning** for autonomous vehicles? CO5 [K2]

19. Compare the advantages and disadvantages of satellite navigation and inertial navigation systems. CO4 [K2]

20. What is "SLAM" for autonomous vehicles? CO5 [K2]

PART C (6 x 5 = 30 Marks)

21. The geographic NED frame is obtained from the ECEF frame by the following rotations: (1) about z-axis by a longitude angle of $-\left(\frac{\pi}{2}+30^{\circ}\right)$, (5) CO1 [K3]

(2) about y-axis by a latitude angle of 30º.

Obtain the DCM required for the conversion from ECEF frame to NED frame.

22. Consider a reference frame rotating at a rate of ω, as shown in Figure 1. Assume an object located in the centre of the reference frame is required to move from point A to point B in a straight line with a constant radial velocity, v. Using the **change in angular momentum** of the object, show that the coriolis acceleration for the object, a_c, is given by, $a_c = 2\vec{\omega}\times\vec{v}$, where '×' is the cross product. (5) CO1 [K3]

(**Hint:** Angular momentum, *H*, is given by $H = mr^2\omega$, where 'm' is the mass of

the object, ‘r’ is the distance of the object from the center of the frame, and the torque is equal to force, *F* times the radius, r.)

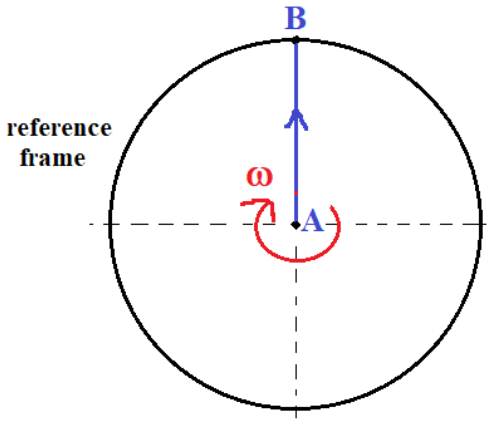

Figure 1.

23. Consider a perfect circular interferometer as shown in Figure 2 with the light constrained to travel around the circumference of a circle of radius R = 5 cm. Light enters the ring at point X, where there is a beam splitter that directs two beams of light in opposite directions around the complete ring, with these beams recombining later at the beam splitter. The interferometer is now rotated with an angular velocity of Ω. Due to the rotation, the time taken for the clockwise light beam to pass around the circumference to reach the beam splitter again is 1.0471976 ns, and for the anticlockwise light beam, the time taken is 1.0471975333 ns. Find the optical path length difference between the two light beams, and from that, find the angular rotation Ω. (5) CO2 [K_3]

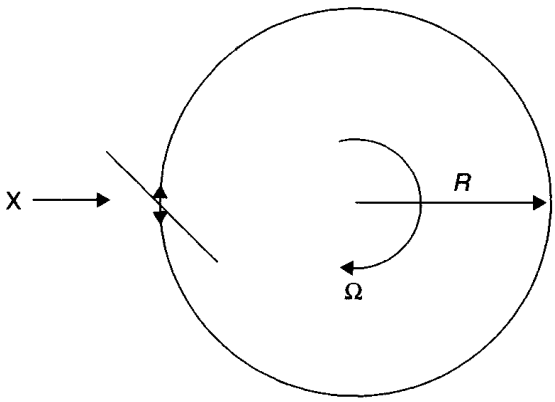

Figure 2.

24. Write the prediction and correction equations of linear Kalman filter. (5) CO4 [K_2]

25. With a neat geometry, explain the line-of-sight guidance for UAVs, and from the geometry, derive the guidance law. (5) CO4 [K_3]

26. Consider Figure 3, which shows nodes (waypoints) connected by edges along with the distance between them. Assume the starting node is "a". (5) CO5 [K3]

Using Dijkstra's algorithm, find the following:

(i) The shortest distance between the starting node and all other nodes by visiting all the nodes and their neighbors.

(ii) The shortest path from node "a" to node "f".

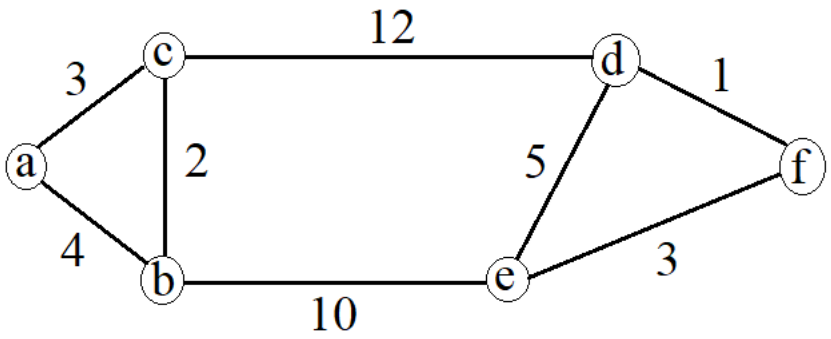

Figure 3.

Answer any FOUR Questions
PART D (4 x 10 = 40 Marks)

27. Explain the force sensed by the MEMS gyroscopes to measure the angular rate. 10 CO2 [K2]

28. Mention the components of GPS satellite signals and explain the basic principle of position determination in GPS. 10 CO3 [K2]

29. Consider an autonomous aerial vehicle that needs to track its position and velocity as it flies to its destination. The vehicle is fitted with a low-cost inertial measurement unit (IMU) that provides direct position and velocity measurements with some noise. Assume a crosswind is pushing the vehicle off the course and there are no commanded inputs to the vehicle. For the vehicle, the states to be estimated are its position (p) and velocity (v). Show the state-space mathematical model of the system dynamics and develop the Kalman filter for estimating the states by showing the state transition matrix, the process (system) covariance matrix (P), and the measurement matrix (H). 10 CO4 [K3]

30. With neat geometry, explain the proportional navigation guidance method for autonomous vehicles. 10 CO4 [K2]

31. Consider the map shown in Figure 4 with its grid of nodes. The white nodes represent the movable areas in the map, and the black nodes represent the 10 CO5 [K3]

obstacles. Using the A* algorithm, find the shortest path from node “A” to node “B”.

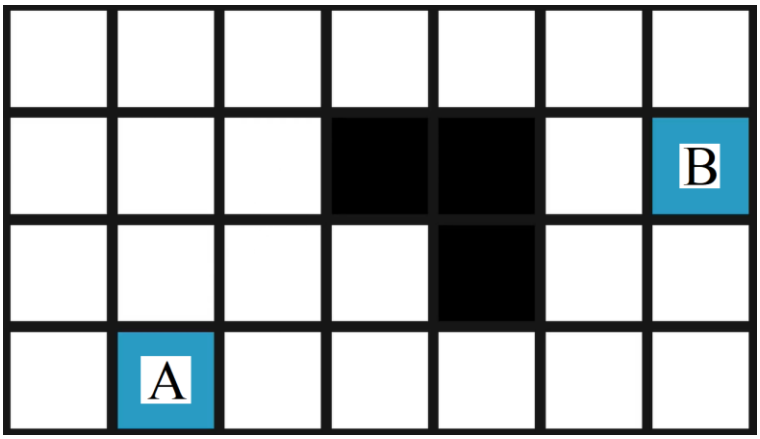

Figure 4.

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