AVIONIC SYSTEM ASSIGNMENT 1

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ASSIGNMENT 1- QUIZ SECTION.

Question 1. Match the following:

Question	**Answer**
a) Altimeter	v) Altitude
b) Gyro Horizon	iii) Pitch and Roll
c) Turn and Slip	ii) Coordinated turn
d) Rate of Climb	i) Vertical speed
e) Directional Gyro	iv) Course

Question 2. Match the following:

Question	**Answer**
a) Power Conversion Equipment	v) Inverter/Transformer Rectifier Unit
b) Integrated Drive Generator	ii) Matching generator capacity with loads
c) Electrical Bonding	iv) Radio interference prevention
d) Batteries	i) Lead Acid
e) Electrical Load Analysis	iii) CSD

Question 3. Match the following:

Question	Answer
a) Indicated Air Speed	iv) Speed shown on the aircraft Air Speed Indicator
b) Equivalent Air Speed	iii) Calibrated Air Speed adjusted for compressibility effects
c) True Air Speed	v) Actual speed of the aircraft wrt surrounding air
d) Calibrated Air Speed	i) IAS adjusted for Instrument and Position errors
e) Ground Speed	ii) Actual speed of the aircraft over ground

Question 4. Main features of EWIS are……

a) Zonal Inspection Procedures (Y)
b) Continued Airworthiness (Y)
c) Covered in FAR 25 Sub part H (Y)
d) Selection of all electrical components in each circuit should be explained and documented. (Y)
e) Wire bundle routings should be specified in drawings and documents . (Y)

Question 5. State TRUE or FALSE

a) Standard Baro Setting (1013mB) is set when flying below the transition altitude. (FALSE)
b) QNH is set when flying below the transition altitude for airfield elevation above mean sea level. (TRUE)
c) Baro setting needs to be carried twice in every flight. (TRUE)

Question 6. Match the following -

Question	Answer
a) Roll	iii) Aileron
b) Handling Qualities	iv) Cooper Harper
c) Slats/Spoilers/Flaps	i) Secondary Control Surfaces
d) Yaw	ii) Rudder
e) Pitch	v) Elevator

Question 7. Match the Following

Question	Answer
a) Fighter Aircraft	iv) F-35
b) Military Transport	vi) C295
c) Passenger Transport Aircraft	v) A320
d) Rotary Wing Aircraft	iii) ALH
e) Agriculture Aircraft	ii) Basant
f) Military Drone	i) CATS

Question 8. State TRUE or FALSE

a) A lower aircraft weight can be achieved by using a FBW, Flight Control System (TRUE)
b) A FBW flight control system needs to have multiply redundant sensors/computation channels/power sources/multiplex actuators in order to match the reliability levels of a mechanical system. (TRUE)
c) A FBW flight control system reduces stress on the pilot by enabling –CAREFREE – handling. (TRUE)

Question 9. Match the Following

Question	Answer
a) Gyroscope	v) Rigidity and precession
b) Schuler Pendulum	ii) Making x and y accelerations zero, z-Acceleration equal to 1g, and provide directional reference
c) Ring Laser Gyro	i) SAGNAC effect
d) Inertial nav system accuracy Specified in …	iv) 84.4 minutes
e) Inertial Navigation System Alignment	iii) NM/hr

Question 10 . State TRUE or FALSE

a) GPS satellites are ‘geo Stationary’ satellites (FALSE)
b) Differential GPS(DGPS) provides higher accuracy using mathematical differentiation processes. (TRUE/FALSE)
c) A HYBRID navigation system is the simultaneous use of more than one navigation systems for position determination. (TRUE/FALSE)
d) An RLG based strap down Inertial Navigation System has a much higher MTBF than a mechanical gyro based platform type IN System. (TRUE/FALSE)

ASSIGNMENT NO 1-TOPICWISE LIST OF QUESTIONS. ELECTRICAL

Question 1. Study the electrical systems architecture of the A 320 aircraft and answer the following questions;

i) What are the power sources on this aircraft?

Primary Power Sources:

- **Engine-Driven Generators (IDG - Integrated Drive Generator)**: Provide **115V AC, 400 Hz** power.
- **Auxiliary Power Unit (APU) Generator**: Supplies power when engines are off.
- **External Power Supply**: Used on the ground from airport systems.

Emergency Power Sources:

- **Ram Air Turbine (RAT)**: Provides emergency power to essential loads.
- **Battery Backup**: Ensures power for critical avionics during failures.

ii) How many buses are used and why?

- The A320 electrical system uses a **structured multi-bus system** to ensure **redundancy and load prioritization**:
    1. **AC Bus 1 & AC Bus 2** – Main power distribution.
    2. **AC Essential Bus** – Powers critical avionics.
    3. **DC Bus 1 & DC Bus 2** – DC loads.
    4. **DC Essential Bus** – Supports vital DC-powered systems.
    5. **Battery Bus** – Emergency power from batteries.
- **Why this structure?**
    - Ensures **continuous power to critical loads** even in case of generator failure.
    - **Isolation of faulty sections** prevents total electrical failure.

iii) In case of failure of a single generator, how are the essential loads supplied?

- If **one generator fails**, the aircraft automatically redistributes loads:
    - **Remaining generator takes over** (via bus tie).
    - **AC Essential Bus** gets power from available AC sources.
    - **DC Bus is supported** by the Transformer Rectifier Unit (TRU).
    - If both generators fail:
        - **Ram Air Turbine (RAT)** deploys to provide **essential flight controls power**.
        - **Battery Backup ensures temporary power** to cockpit displays and avionics.

iv) How is the battery getting charged?

- The **batteries are charged** by the **aircraft's DC bus**, which is powered by:
    - **Transformer Rectifier Units (TRU)** – Convert AC to DC.
    - **Charging Regulators** – Maintain battery voltage and prevent overcharging.

v) Which are the power conversion devices used?

- **Power Conversion Devices in A320:**
    - **Integrated Drive Generator (IDG)** – Converts engine rotational speed to **constant AC power**.
    - **Transformer Rectifier Unit (TRU)** – Converts **AC to DC**.
    - **Static Inverter** – Converts **DC back to AC** for backup systems.

Question 2. Study the material on ‘Electrical Load Analysis’ and answer the following questions;

i) Why is it necessary to assess the electrical loads during each phase of flight?

- Aircraft operate under different electrical demands during **Takeoff, Cruise, and Landing**.
- **Load analysis ensures:**
    - Sufficient power for **critical systems**.
    - No overloading of **generators & busbars**.
    - Emergency power backup calculations.

ii) How is the battery capacity needed being estimated?

- Battery capacity is calculated based on:
    - **Minimum required backup time** (e.g., 30 min of emergency operation).
    - **Total essential power consumption** (avionics, communication, lighting).
    - **Voltage & current requirements** of critical loads.

Formula:

$$\text{Battery Capacity (Ah)} = \frac{\text{Total Load (W)}}{\text{Battery Voltage (V)}}$$

iii) Why is it necessary to ‘update’ the load analysis after every modification?

- Any new avionics, lighting, or electrical system **modifications change power requirements**.
- Updating ensures:
    - **No overloading of generators**.
    - **Redundancy remains intact** for emergency operations.

iv) How are the loads classified and assigned to various busbars?

- **Essential Loads** → AC/DC Essential Bus (Avionics, Cockpit Displays).
- **Primary Loads** → AC/DC Bus 1 & 2 (Cabin, Lighting, Pumps).
- **Non-Essential Loads** → Shed Bus (Entertainment, Galley Power).

Question 3. a) Describe the operation of a 'constant speed drive'. What is the advantage of an 'Integrated Drive Generator'?

Constant Speed Drive (CSD):

- **Maintains a constant rotational speed for generators.**
- **Uses hydraulic-mechanical gears to adjust varying engine speeds.**

Integrated Drive Generator (IDG) - Advantage:

- **Combines CSD & Generator in one unit, reducing weight & complexity.**
- **Better reliability with self-monitoring capabilities.**

Question 4. a) What is avionics architecture? Distinguish between federated and avionics integrated modular architecture.

- **Avionics Architecture refers to the design framework of electronic systems in an aircraft.**

Federated vs Integrated Modular Architecture (IMA)

Feature	**Federated Architecture**	**Integrated Modular Avionics (IMA)**
Structure	**Separate, independent avionics for each function**	**Centralized processing units**
Weight	**Heavier, multiple systems**	**Lighter, fewer systems**
Cost	**Higher, due to redundancy**	**Lower, due to shared resources**
Example	**Boeing 747 classic**	**Airbus A350, Boeing 787**

b) Describe the main features of the avionics architecture for a commercial passenger aircraft.

High Redundancy – Ensures continuous operation in failures.

Digital Fly-by-Wire (FBW) – Replaces mechanical linkages.

Integrated Display Systems – Glass Cockpit for better situational awareness.

Networked Communication – Uses ARINC 429/AFDX protocols.

AIR DATA

Question 5. a) What is the importance of 'International Standard Atmosphere'?

The **International Standard Atmosphere (ISA)** is a globally accepted reference model used to define **temperature, pressure, density, and other atmospheric properties** at various altitudes. It is essential for:

1. **Aircraft Performance Calculation**
   - Used to determine **lift, drag, engine efficiency, and fuel consumption** under standardized conditions.
   - Helps in **designing and certifying aircraft** to ensure uniform performance globally.
2. **Calibration of Instruments**
   - Altimeters, airspeed indicators, and other avionics are calibrated based on **ISA-defined temperature and pressure**.
3. **Standardization in Aviation & Aerospace Engineering**
   - **Ensures consistency** across different aircraft and operational procedures.
   - Used in **ATC (Air Traffic Control), aircraft certification, and weather forecasting**.
4. **Comparison with Real Atmospheric Conditions**
   - Pilots and engineers compare actual **flight conditions with ISA values** to account for **temperature deviations** affecting aircraft performance.

b) If the temperature at zero altitude is 90 deg F , what is the temperature at an altitude of 15,000 meters?

The ISA model defines a standard lapse rate, where temperature decreases with altitude.

ISA Temperature Lapse Rate:

$$\text{Temperature Drop} = -6.5^{\circ}C \text{ per } 1000 \text{ meters}$$

Given Data:

- **Sea Level Temperature: 90°F**
- **Convert to Celsius:**

$$T_0 = \frac{(90 - 32) \times 5}{9} = 32.22^{\circ}C$$

Altitude: 15,000 meters

Temperature Decrease:

$$(15,000 \text{ m} \times -6.5^{\circ}C \text{ per km}) = -97.5^{\circ}C$$

Final Temperature:

$$T = 32.22 - 97.5 = -65.28^{\circ}C$$

Answer:

At 15,000 meters, the temperature will be approximately -65.28°C.

Note: This is based on the ISA standard lapse rate and does not consider

c) What is the Mach number of an aircraft flying at 20,000 feet above MSL if the temperature at sea level is 20 deg C and the true air speed is 500 knots?

Mach Number (M) is the ratio of an aircraft's true airspeed (TAS) to the speed of sound (a) at a given altitude:

$$M = \frac{\text{TAS}}{\text{Speed of Sound}}$$

Step 1: Convert Given Data to SI Units

- **True Air Speed (TAS) = 500 knots**

$$500 \times 1.852 = 926 \text{ km/h} = 926,000/3600 = 257.22 \text{ m/s}$$

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- **Altitude: 20,000 feet**

$$20,000 \times 0.3048 = 6,096 \text{ meters}$$ **Sea Level Temperature: 20°C**

  - **ISA Lapse Rate: -6.5°C per 1000 m**
  - **Temperature at 6,096 m:**

$$T = 20 - (6.5 \times 6.096) = 20 - 39.62 = -19.62^{\circ}C$$

Step 2: Calculate Speed of Sound at 6,096m

Speed of sound (aaa) in dry air is given by:

$$a = \sqrt{\gamma RT}$$

Where:

$\gamma = 1.4$ (Ratio of specific heats for air)

$R = 287$ J/kg.K (Gas constant for air)

T in **Kelvin**:

$$T = -19.62 + 273.15 = 253.53K$$

$$a = \sqrt{1.4 \times 287 \times 253.53}$$

$$a = \sqrt{101931.7} = 319.27 \text{ m/s}$$

Step 3: Compute Mach Number

$$M = \frac{TAS}{a} = \frac{257.22}{319.27} = 0.81$$

Final Answer:

The Mach number at 20,000 feet for 500 knots TAS is approximately 0.81.

Conclusion: The aircraft is flying at subsonic speed, close to the transonic range

$(M \approx 0.8)$.

Question 6. a) Explain the computations carried out in an 'air data computer'.

Introduction to Air Data Computer (ADC)

An Air Data Computer (ADC) is an essential avionics system in modern aircraft, responsible for processing air pressure and temperature sensor inputs to compute critical flight parameters. The output from the ADC is used by several onboard systems, including flight controls, autopilot, and cockpit displays.

Key Computations Performed by the Air Data Computer

1. Altitude Computation (Pressure Altitude)

- The ADC measures static pressure from the pitot-static system.
- It calculates pressure altitude using the International Standard Atmosphere (ISA)

$$P = P_0 \left(1 - \frac{Lh}{T_0}\right)^{\frac{gM}{RL}}$$

Where:

- P = Pressure at altitude
- P_0 = Sea level pressure (1013.25 hPa)
- L = ISA temperature lapse rate (-6.5°C per km)
- h = Altitude in meters
- T_0 = ISA sea level temperature (15°C)
- g = Gravitational acceleration (9.81 m/s²)
- M = Molar mass of air (0.029 kg/mol)
- R = Universal gas constant (8.314 J/mol·K)

The computed **pressure altitude** is used for **autopilot, ATC transponders, and altitude warnings**.

2. Airspeed Computation (Indicated & True Airspeed)

- **Indicated Airspeed (IAS):**
  - Computed using **differential pressure** between **pitot tube (total pressure) and static pressure:**

$$q_c = P_t - P_s$$

  - ADC then applies airspeed calibration tables to correct instrument errors.

- **True Airspeed (TAS):**
  - Corrected IAS for **altitude and temperature effects** using:

$$TAS = IAS \times \sqrt{\frac{\rho_0}{\rho}}$$

  - ρ_0 = Air density at sea level
  - ρ = Air density at flight altitude

- **Mach Number Calculation:**

$$M = \frac{\text{TAS}}{\text{Speed of Sound (a)}}$$

  - **Speed of Sound (a)** is calculated based on **air temperature (T):**

$$a = \sqrt{\gamma R T}$$

    - $\gamma = 1.4$ (for dry air)
    - $R = 287$ J/kg·K (specific gas constant for air)

- **Application:** The calculated airspeed values are crucial for **flight controls, autopilot, and stall warning systems.**

3. Vertical Speed Computation (Rate of Climb/Descent)

- **The ADC differentiates static pressure over time:**

$$V_s = -\frac{dP}{dt} \times \frac{1}{\rho g}$$

- V_s = Vertical Speed (ft/min or m/s)
- P = Static Pressure
- ρ = Air Density

Application: Used in vertical speed indicators (VSI) and flight management systems (FMS).

4. Outside Air Temperature (OAT) & Total Air Temperature (TAT)

- **OAT (Ambient Temperature):** Directly measured by sensors.
- **TAT (Corrected for Ram Effect):** Used in **engine performance calculations.**

$$T_{total} = T_{static} \times \left(1 + \frac{\gamma - 1}{2} M^2\right)$$

- **Application:** Used for **icing warnings, engine efficiency optimization, and Mach number calculations.**

5. Density Altitude Calculation

- Density altitude is computed using:

$$\text{Density Altitude} = \text{Pressure Altitude} + (120 \times (T - T_{\text{ISA}}))$$

- **Application:** Used in **performance charts for takeoff, climb rate, and landing distance calculations.**

6. Wind Speed & Direction Estimation

- ADC combines **true airspeed, inertial navigation, and GPS data** to calculate **wind components:**
  - **Wind Speed** = Difference between **ground speed (GPS) and airspeed (TAS)**
  - **Wind Direction** = Angle between aircraft heading and actual track
- **Application:** Used for **navigation, auto-throttle, and fuel optimization.**

7. Static Source Error Correction (SSEC)

- The ADC applies **calibration corrections** to account for **instrument and installation errors** in the static pressure system.

The Air Data Computer (ADC) plays a crucial role in modern aircraft by computing altitude, airspeed, Mach number, vertical speed, temperature, and wind data. These computations ensure accurate navigation, flight safety, and optimal aircraft

Question 7. b) What are the various systems needing air data? Explain why they are needed?

Introduction

Air data refers to **parameters derived from air pressure, temperature, and velocity measurements**. These parameters, such as **altitude, airspeed, Mach number, vertical speed, and density altitude**, are crucial for various aircraft systems.

The **Air Data Computer (ADC)** processes these inputs and provides accurate data to multiple onboard systems for **navigation, control, and performance optimization**.

Systems Needing Air Data & Their Importance

System	Why Air Data is Needed?
1. Flight Management System (FMS)	Uses altitude, airspeed, and wind data for route optimization, fuel efficiency, and autopilot adjustments.
2. Autopilot & Flight Control System	Requires altitude, airspeed, and Mach number for stability control, smooth maneuvering, and maintaining set flight parameters.
3. Engine Control System (FADEC)	Uses total air temperature (TAT) and Mach number to optimize fuel mixture and engine thrust at different altitudes.
4. Cockpit Display Systems (EFIS, PFD)	Displays altitude, speed, and vertical speed to the pilot, ensuring situational awareness and adherence to flight plans.
5. Altitude Alerting & Transponder Systems (Mode C/S, ADS-B)	Uses pressure altitude data for ATC communication, collision avoidance, and separation management.
6. Stall Warning & Protection Systems	Monitors airspeed and angle of attack (AOA) to prevent stall conditions.
7. Ground Proximity Warning System (GPWS/TAWS)	Uses altitude and descent rate data to alert pilots of terrain proximity and potential hazards.
8. Weather Radar & Turbulence Detection	Uses airspeed and temperature to assess wind shear, turbulence, and weather patterns.
9. Pitot-Static Instruments (Airspeed Indicator, Altimeter, VSI)	Directly relies on air data for manual pilot control and backup reference in case of system failure.
10. Navigation Systems (GPS, INS, ADS-B, TCAS)	Uses air data for accurate aircraft position tracking, wind correction, and avoidance maneuvers.

Key Air Data Parameters Used by These Systems

1. **Altitude (Pressure & Density Altitude)**
    - **Used for navigation, autopilot, ATC transponders, and performance calculations.**
2. **Airspeed (IAS, TAS, Mach)**
    - **Ensures accurate flight performance, stall prevention, and engine efficiency.**

3. **Vertical Speed (Rate of Climb/Descent)**
    - **Used by autopilot, VSI, and GPWS systems for smooth altitude transitions.**
4. **Total Air Temperature (TAT)**
    - **Helps in engine performance monitoring, icing warnings, and Mach number calculation.**
5. **Wind Speed & Direction**
    - **Crucial for navigation, fuel efficiency, and approach/landing procedures.**

Air data is critical for flight safety, efficiency, and control. The ADC processes air data and distributes it to multiple subsystems, ensuring smooth operation of navigation, engine management, and pilot displays.

FLIGHT CONTROL

Question 8. a) Explain the concept of 'longitudinal stability' of an aircraft.

(a) Longitudinal Stability of an Aircraft

Definition

Longitudinal stability refers to the **aircraft's tendency to return to level flight (equilibrium) after a pitch disturbance** (nose-up or nose-down movement) without pilot intervention.

Key Factors Affecting Longitudinal Stability

1. **Center of Gravity (CG) Position:**
    - **Forward CG** improves stability but increases drag.
    - **Aft CG** reduces stability but enhances maneuverability.
2. **Tailplane & Horizontal Stabilizer:**
    - Generates a **balancing force** to counteract pitch disturbances.

    - If the nose pitches up, the tailplane produces **downward force** to restore equilibrium.
3. **Wing Aerodynamics:**
    - **Wing position & dihedral angle** affect stability.
    - A **high-wing design** contributes more to natural stability.
4. **Stick-Free & Stick-Fixed Stability:**
    - **Stick-Fixed Stability:** Stability when control surfaces remain fixed.
    - **Stick-Free Stability:** Stability when control forces are relaxed.

Static vs. Dynamic Longitudinal Stability

Type	Explanation
Static Stability	Immediate aircraft response to a disturbance. A statically stable aircraft resists excessive pitch changes.
Dynamic Stability	How an aircraft responds over time after a disturbance. If it oscillates and settles back to its original state, it has **positive dynamic stability**.

Importance of Longitudinal Stability

- Ensures **smooth flight control**.
- Reduces **pilot workload**.
- Prevents **pitch oscillations** that could cause pilot disorientation.
- Affects **aircraft performance in turbulence and high-speed flight**.

b) What do you understand by the term 'stability augmentation systems'? Why are they needed?

A Stability Augmentation System (SAS) is an electronic control system that improves aircraft stability by automatically correcting deviations in pitch, roll, or yaw.

Why Are They Needed?

- Modern aircraft, especially fighter jets, commercial airliners, and UAVs, require automated stability control for safety and efficiency.
- Aircraft with relaxed static stability (RSS) (such as Fly-By-Wire systems) cannot be flown manually without augmentation.

Types of Stability Augmentation Systems

1. Pitch Stability Augmentation:
    - Automatically corrects nose-up/nose-down deviations.

- Used in autopilots, Airbus Fly-By-Wire systems.

2. Yaw Damping System (Yaw Damper):
   - Prevents Dutch Roll (yaw-induced oscillations) in high-speed jets.
3. Roll Stability Augmentation:
   - Adjusts ailerons automatically to maintain roll balance.
   - Important for fighter jets & high-speed commercial aircraft.
4. Auto-Trim Systems:
   - Adjusts elevator trim based on flight conditions.
5. Artificial Stability in Fly-By-Wire (FBW) Systems:
   - Example: Airbus and Boeing aircraft use digital flight control systems to correct instability dynamically.

Application of Stability Augmentation

Aircraft Type	SAS Role
Commercial Jets (A320, B737, etc.)	Ensures smooth, automated flight stability.
Fighter Jets (F-22, Rafale, etc.)	Enhances maneuverability while maintaining control.
Helicopters	SAS helps counteract instability due to rotor blade aerodynamics.
UAVs/Drones	Autopilot stability augmentation allows remote control operations.

Question 9. Explain with a block diagram the concept of a quadruplex system configuration for a 'fly by wire' flight control system on a commercial aircraft.

Concept of Quadruplex System in Fly-By-Wire (FBW)

A quadruplex Fly-By-Wire (FBW) system is a four-channel redundant digital control system that replaces mechanical linkages with electronic signals for flight control. It ensures high reliability, fault tolerance, and precision in controlling the aircraft.

Key Components of a Quadruplex FBW System:

1. Pilot Input (Sidestick/Control Yoke) – Sends electronic signals to the flight control computers.
2. Flight Control Computers (FCCs)
   - Quadruplex (4-channel) redundant architecture.
   - Compares data and applies control laws.
3. Actuators & Servo Motors
   - Receive processed signals and adjust control surfaces.

4. Sensors (Gyros, Air Data, Accelerometers)
    - Provide real-time flight data for stability augmentation.
5. Redundant Power Supply
    - Ensures continuous operation in case of failure.

Advantages of Quadruplex FBW System:

- High fault tolerance (multiple backups).
- Improved precision and safety.
- Weight reduction compared to mechanical systems.
- Automatic stability augmentation.

Question 10. What do you understand by the term 'handling characteristics of an aircraft? Explain the 'Cooper-Harper scale'.

Handling Characteristics of an Aircraft

Handling characteristics refer to how an aircraft responds to pilot inputs and external conditions such as turbulence. It includes stability, control responsiveness, maneuverability, and workload required to fly safely.

Factors Affecting Handling Characteristics:

- Control sensitivity (how easily the aircraft responds).
- Stability (longitudinal, lateral, and directional).
- Pilot workload (effort required to maintain flight).

Cooper-Harper Scale (Handling Qualities Rating Scale)

The Cooper-Harper Rating Scale is a subjective pilot evaluation system used to assess handling qualities. It rates aircraft on a 1-10 scale, where:

- 1-3: Excellent handling, minimal effort.
- 4-6: Satisfactory with some pilot compensation needed.
- 7-9: Poor handling, difficult to control.
- 10: Unacceptable, extremely hard to control.

Question 11. What are the advantages of a ‘fly by wire’ flight control system?

Advantages of Fly-By-Wire (FBW) Systems

1. Weight Reduction
   - Eliminates heavy mechanical linkages.
2. Improved Safety
   - Multiple redundant computers prevent failures.
3. Enhanced Stability
   - Stability Augmentation Systems (SAS) reduce pilot workload.
4. Flight Envelope Protection
   - Prevents excessive maneuvering that could lead to stalls or overstress.
5. Fuel Efficiency
   - Optimized control movements reduce drag.
6. Better Maneuverability
   - Adaptive flight control laws improve response.

Examples of Aircraft Using FBW:

- Airbus A320, A350, A380
- Boeing 787 Dreamliner
- Military jets F-22 Raptor, Dassault Rafale

Question 12. Explain the different forms of ‘flight control actuation’ and the surfaces to which they are normally applied.

Forms of Flight Control Actuation

1. Manual Actuation – Pilot directly moves control surfaces using cables and pulleys. *(Used in small aircraft.)*
2. Hydraulic Actuation – Hydraulic pressure moves control surfaces. *(Used in commercial aircraft and fighter jets.)*
3. Electrical Actuation (Power-by-Wire) – Uses electric motors instead of hydraulic fluid. *(Used in modern aircraft like B787.)*
4. Electro-Hydrostatic Actuation (EHA) – Self-contained actuators combining hydraulic and electric power. *(Reduces complexity in FBW systems.)*

Control Surfaces and Their Actuation

Control Surface	Function	Actuation Type
Ailerons	Roll control	Hydraulic/Electric
Elevators	Pitch control	Hydraulic/Electric
Rudder	Yaw control	Hydraulic/Electric
Flaps/Slats	Lift augmentation	Hydraulic/Electric
Spoilers	Drag control	Hydraulic/Electric

Question 13. Explain the functioning of the 'flight management system' on a modern commercial aircraft.

Definition

The Flight Management System (FMS) is an integrated avionics system that automates flight planning, navigation, performance optimization, and guidance.

Components of an FMS:

1. Flight Plan Database
   - Stores preloaded routes and procedures.
2. Navigation System
   - Uses GPS, INS, and radio navigation aids.
3. Performance Management
   - Calculates fuel efficiency, speed, and altitude profiles.
4. Autothrottle & Autopilot Integration
   - Automates control for optimized flight.
5. Human-Machine Interface (HMI)
   - Pilots input data via Control Display Units (CDU) or touchscreen interfaces.
   -

FMS Functionality During Flight Phases

Flight Phase	FMS Role
Pre-Flight	Flight route input, fuel calculation
Takeoff	Optimal power setting, navigation check
Cruise	Fuel efficiency monitoring, navigation updates
Descent & Landing	Autopilot approach, landing guidance

Benefits of FMS

- Reduces pilot workload by automating navigation and performance tasks.
- Improves fuel efficiency with optimized cruise speeds.
- Enhances safety with precise flight path management.

DISPLAY

Question 14. a) Explain the concept of the 'head-up display' (HUD).

Concept of HUD

A Head-Up Display (HUD) is a transparent display system that projects critical flight data onto a combiner glass or visor, allowing pilots to view essential information without looking down at cockpit instruments.

Key Components of a HUD

1. Combiner Glass – A transparent screen that reflects data.
2. Projector Unit – Projects flight data onto the combiner.
3. Computer Processing Unit – Generates real-time graphics using avionics data.
4. Symbol Generator – Converts flight data into visual symbols.

Advantages of HUD

- Improves situational awareness (pilots focus on outside view).
- Reduces pilot workload (critical data displayed in line of sight).
- Enhances safety in low visibility conditions (fog, night landing)

Question 14. b) Difference between Total Field of View (TFOV) and Instantaneous Field of View (IFOV)

Parameter	Total Field of View (TFOV)	Instantaneous Field of View (IFOV)
Definition	The entire area visible through the display.	The portion of the TFOV viewed at any instant.
Size	Large, covers the full scene.	Small, depends on HUD/eye movement.
Impact	Determines how much information is visible at once.	Affects clarity and readability of projected symbols.

Monocular Vision vs. Binocular Vision

Vision Type	Definition	Example in HUD
Monocular Vision	Single eye perceives the display.	One-eye view of HUD symbols.
Binocular Vision	Both eyes receive the same image for depth perception.	Modern HUDs optimize for binocular viewing.

Question 14. c) Why does the HUD need 'high brightness' CRTs?

- Visibility in bright daylight – Aircraft cockpits have high ambient light.
- Enhanced contrast – Ensures symbology is sharp against external scenery.
- Reduced eye strain – Improves readability during long flights.

Alternative: Modern HUDs use Liquid Crystal Display (LCD) or Organic LED (OLED) technology instead of CRTs for better brightness and efficiency.

Question 15. a) Explain the concepts of 'cockpit ergonomics' and 'pilot workload'.

Cockpit Ergonomics

Cockpit ergonomics focuses on the design and arrangement of flight controls, displays, and seating to maximize pilot efficiency and minimize fatigue.

Key Principles of Cockpit Ergonomics

1. Intuitive Control Layout – Buttons and switches positioned for ease of access.
2. Reduced Pilot Fatigue – Comfortable seating, adjustable instrument positions.
3. Minimized Cognitive Load – Clear, organized displays prevent information overload.

Pilot Workload

Pilot workload refers to the mental and physical effort required to operate an aircraft. High workload increases stress and the risk of errors.

Factors Affecting Pilot Workload

- Complexity of cockpit instruments.
- Autopilot & automation (reduces workload).
- Weather conditions & air traffic congestion.

Question 15. b) Difference between a 'Conventional Cockpit' and a 'Glass Cockpit'

Cockpit Type	Conventional Cockpit	Glass Cockpit
Displays	Analog dials & gauges	Digital LCD or LED screens
Information Layout	Spread across multiple instruments	Integrated into a few large displays
Workload	Higher workload, manual monitoring	Reduced workload, automated alerts
Examples	Boeing 737-200, DC-9	Airbus A320, Boeing 787

Example of a Glass Cockpit

- Uses Electronic Flight Instrument System (EFIS) with Primary Flight Display (PFD) and Multi-Function Display (MFD).

Question 16. Briefly Compare the Technologies Used in 'Electronic Displays'

Electronic displays have evolved from Cathode Ray Tube (CRT) displays to modern Liquid Crystal Displays (LCD) and Organic LED (OLED) screens.

Display Type	Technology	Advantages	Examples in Aircraft
Cathode Ray Tube (CRT)	Electron beams strike a phosphor-coated screen.	High brightness, durable.	Old HUDs, radar screens.
Liquid Crystal Display (LCD)	Liquid crystals modulate light from a backlight.	Low power, lightweight.	Modern cockpit displays.
Organic LED (OLED)	Self-emitting pixels, no backlight needed.	High contrast, energy efficient.	Newer HUDs, EVS displays.
Active-Matrix LCD (AMLCD)	Advanced LCD with rapid refresh rates.	Sharp, clear images.	Boeing 787, Airbus A350.

NAVIGATION-1

Question 17. (a) Distinguish between 'Dead Reckoning' and 'Position Fixing'

Parameter	**Dead Reckoning**	**Position Fixing**
Definition	Navigation method using known position, heading, speed, and time to estimate the next position.	Determining the exact position using external references such as celestial objects, radio signals, or satellites (GPS).
Accuracy	Less accurate over time due to cumulative errors from wind drift and speed variations.	More accurate as it relies on real-time external references.
Instruments Used	Compass, airspeed indicator, clock, inertial navigation systems.	GPS, VOR/DME, celestial navigation, radar.
Application	Backup navigation when GPS or radio signals are unavailable (used in military and emergency navigation).	Primary method for modern aircraft using GPS and other aids.

Example:

- **Dead Reckoning:** A pilot estimates the aircraft's next position using speed, time, and heading.
- **Position Fixing:** A pilot uses GPS or VOR signals to determine the exact current location.

Question 17. (b) Calculate the Distance Between Bengaluru and Chennai (Great-Circle Distance)

Step 1: Convert Latitude & Longitude to Decimal Degrees

- **Bengaluru:**
  - Latitude: **12° 75' N → 13.25° N**
  - Longitude: **78° 35' E → 78.5833° E**
- **Chennai:**
  - Latitude: **13° 5' N → 13.0833° N**
  - Longitude: **80° 16' E → 80.2667° E**

Step 2: Apply the Haversine Formula

The **Haversine formula** calculates the great-circle distance (ddd) between two points on a sphere:

$$a = \sin^2\left(\frac{\Delta\varphi}{2}\right) + \cos(\varphi_1)\cos(\varphi_2)\sin^2\left(\frac{\Delta\lambda}{2}\right)$$

$$c = 2 \times \operatorname{atan2}\left(\sqrt{a}, \sqrt{1-a}\right)$$

$$d = R \times c$$

Where:

- φ_1, φ_2 = Latitudes of Bengaluru and Chennai (radians).
- $\Delta\varphi = \varphi_2 - \varphi_1$ (latitude difference in radians).
- $\Delta\lambda = \lambda_2 - \lambda_1$ (longitude difference in radians).
- $R = 6371$ km (Earth's radius).

Using the formula, we get:

$$d \approx 285 \text{ km}$$

Thus, the **great-circle (shortest) distance between Bengaluru and Chennai is approximately 285 km**.

Question 18. (a) Explain the basic concept of the 'Inertial Navigation System' (INS).

Concept of Inertial Navigation System (INS)

An **Inertial Navigation System (INS)** is a **self-contained navigation system** that uses **accelerometers and gyroscopes** to track an object's position, velocity, and orientation **without requiring external references** like GPS.

Working Principle of INS

1. **Accelerometers** measure changes in velocity along different axes.
2. **Gyroscopes** measure angular changes (rotation) around these axes.
3. **Integration of Accelerations** over time provides velocity and position.
4. **Dead Reckoning Method** is used to update the current location.

Advantages of INS

- **Works in GPS-denied environments** (e.g., military applications, submarines).
- **Unaffected by external interference** (jamming, signal loss).
- **Highly precise for short durations**, especially in aircraft and spacecraft.

Question 18. (b) Difference between Stable Platform Configuration and Strap-Down Configuration

Feature	Stable Platform INS	Strap-Down INS
Gyro Type	Uses mechanical gyros to maintain a fixed reference frame.	Uses solid-state gyros (e.g., Ring Laser Gyros).
Configuration	A **gimbal-mounted platform** stabilizes the accelerometers.	Accelerometers are directly attached to the aircraft body (fixed).
Weight & Complexity	Heavy and complex due to moving parts.	Lightweight, simpler, and more reliable.
Performance	Very accurate but requires frequent maintenance.	Modern algorithms allow high accuracy without a stable platform.

Advantages of Ring Laser Gyro (RLG) Based Strap-Down INS Over Mechanical Gyro-Based Stable Platform INS

- **No Moving Parts** → Increases reliability and lifespan.
- **Less Drift & Higher Accuracy** → Eliminates friction errors in mechanical gyros.
- **Compact & Lightweight** → More suited for modern aircraft.
- **Fast Alignment & Start-Up** → Reduces pre-flight calibration time.

Question 19. (a) What is a ‘Schuler Pendulum’?

A **Schuler Pendulum** is a **theoretical pendulum** with a period equal to **84.4 minutes**, the same as the **time a satellite would take to orbit Earth at its surface**. It is a key concept in **inertial navigation**.

Why Is It Important?

- Ensures **INS does not drift excessively over time** due to Earth’s curvature.
- Helps INS maintain alignment with the **local vertical**.
- Basis for **Schuler Tuning**, which stabilizes **long-term navigation accuracy**.

Question 19. (b) What is an 'Earth-Centered Earth-Fixed' (ECEF) coordinate system?

Definition

The **Earth-Centered Earth-Fixed (ECEF)** coordinate system is a **global Cartesian coordinate system** used in navigation and geolocation.

Key Features

- **Origin is at Earth's center** (0,0,0).
- **X-axis points towards the prime meridian.**
- **Z-axis aligns with the North Pole.**
- **Rotates with the Earth**, making it useful for **GPS and satellite navigation**.

Question 19. (c) What is WGS 84? Why is a consistent earth model needed with different navigation systems on an aircraft?

What is WGS 84?

The **World Geodetic System 1984 (WGS 84)** is a **global reference model** for mapping, navigation, and satellite positioning. It defines:

- **Earth's shape** as an oblate spheroid.
- **Coordinate system** for GPS and aircraft navigation.
- **Reference frame** for positioning worldwide.

Why is a Consistent Earth Model Needed?

1. **Ensures Compatibility Among Navigation Systems**
    - GPS, INS, and radio navigation must use the **same coordinate reference** for accuracy.
2. **Reduces Positioning Errors**
    - Different earth models could lead to **inconsistent location data**.
3. **Standardization in Aviation**
    - ICAO and FAA mandate **WGS 84** for air navigation databases.

NAVIGATION-2

Question 20. (a) Briefly describe the operation of the ADF system covering the following:

Automatic Direction Finder (ADF)

The **ADF (Automatic Direction Finder)** is a radio navigation system that determines the bearing of an aircraft relative to a **Non-Directional Beacon (NDB)**.

(i) Why does it need two antennas? (Sense and Loop Antennas)

- **Loop Antenna:**
  - Detects the direction of incoming radio waves.
  - Produces a **figure-eight reception pattern** with **two nulls** (directions where the signal disappears).
  - Can **detect bearing but has 180° ambiguity** (cannot distinguish front or back).
- **Sense Antenna:**
  - Omnidirectional reception with no directional information.
  - Used to resolve **bearing ambiguity** of the loop antenna.
  - When combined with the loop antenna, it creates a **cardioid pattern**.

(ii) What is the significance of the cardioid pattern generated by these antennas?

- The **cardioid pattern** results from the **combination of loop and sense antenna signals**.
- It **removes the 180° ambiguity**, ensuring the ADF points **directly to the NDB**.

(iii) What is the range of the ADF system?

- **Typical range:** 50-200 NM (nautical miles), **depending on NDB power and weather conditions**.
- **Higher-power NDBs** can provide a range of **400 NM or more**.

- **ADF is affected by thunderstorms, terrain, and night-time atmospheric conditions.**

(iv) How can you obtain present position on a map by tuning to two or more stations?

- **Bearing Intersection Method:**
    1. Tune into **two different NDB stations**.
    2. Plot the **ADF bearings** from each station on a map.
    3. The point where the two lines **intersect is the aircraft's current position**.
    4. This method is known as **"position fixing"**.

Question 21. (a) What is the operating principle of the VOR?

- **VOR (VHF Omnidirectional Range)** is a **radio navigation system** used to determine an aircraft's bearing relative to a ground station.
- **Operating Frequency:** 108.00 – 117.95 MHz.
- **Principle:**
    - The VOR station transmits **two signals**:
        1. **Reference Signal** (Omnidirectional).
        2. **Variable Signal** (Rotating 360° around the station).
    - The aircraft's **VOR receiver** measures the **phase difference** between these signals to determine the **radial** (bearing) from the station.

Question 21. (b) What is DVOR?

- **Doppler VOR (DVOR)** is an **improved VOR system** with enhanced accuracy.
- **Key Difference:**
    - Instead of a **stationary transmitter**, **DVOR uses a rotating Doppler antenna**.
- **Advantages of DVOR:**
    - **More accurate** than conventional VOR.
    - **Less interference** from terrain and atmospheric conditions.
    - **Lower maintenance** compared to conventional VOR.

Question 21. (c) Comparison of ADF and VOR Operations

Feature	ADF (Automatic Direction Finder)	VOR (VHF Omnidirectional Range)
Operating Frequency	190 kHz – 1750 kHz (LF/MF)	108 – 117.95 MHz (VHF)
Principle	Uses NDB signals to determine bearing.	Measures phase difference between two signals for accurate radial determination.
Accuracy	Less accurate, affected by interference.	Highly accurate (±1° deviation).
Weather Interference	Affected by thunderstorms, terrain reflections.	Less affected, more reliable.
Range	50 – 200 NM (up to 400 NM for powerful NDBs).	40 – 130 NM, depending on altitude.
Indicator Used	Radio Magnetic Indicator (RMI), ADF needle.	Course Deviation Indicator (CDI), Horizontal Situation Indicator (HSI).
Application	Long-range navigation over water and remote areas.	Used for en-route navigation and instrument approaches.

Question 22. What are the limitations of the DME system?

1. **Slant-Range Error:**
    - DME measures the **direct distance between the aircraft and the station**, not the horizontal ground distance.
    - At high altitudes, the displayed distance is **not the true ground distance**.
2. **Line-of-Sight Requirement:**
    - DME operates in the **UHF band (960-1215 MHz)**.
    - If mountains or terrain obstruct the signal, it results in **signal loss**.
3. **Limited Coverage at Low Altitudes:**

- Aircraft at very low altitudes may not receive DME signals due to **horizon limitations**.

4. **Limited Range:**
    - **Typical range is 200 to 300 NM**, depending on altitude and power of the ground station.
5. **Interference & Congestion:**
    - A DME station can handle **only a limited number of aircraft (100-200 max) simultaneously**.

Question 23. Why do ADF/VOR/DME systems continue to operate even after GPS is available for all applications?

- **Redundancy and Backup for GPS Failures**
    - GPS can be **jammed or unavailable** (solar storms, military disruptions).
    - ADF, VOR, and DME provide **critical backups**.
- **Regulatory Requirements**
    - Many **airways and approach procedures still rely on ground-based navigation**.
- **Cost and Practicality**
    - Upgrading all aircraft to GPS-based navigation is **expensive**.
    - Many **general aviation aircraft still use ADF and VOR**.
- **Reliability in Certain Environments**
    - **ADF is useful in high-latitude regions** where **GPS signals weaken**.
    - **VOR/DME provide stable navigation for many commercial aircraft.**

Question 24. Discuss antenna locations on a commercial aircraft. Why do some systems have dual antennas?

- **Antenna Placement:**
    - **VHF Antennas:** Top & bottom of the fuselage (for ATC communication).
    - **HF Antennas:** Horizontal stabilizer or fuselage-mounted.

- **GPS Antennas:** On top of the fuselage (for clear satellite reception).
- **DME Antennas:** Underside of the fuselage.
- **TCAS Antennas:** One on the top and one on the bottom.

- **Why Dual Antennas?**

1. **Redundancy** – Prevents failure of critical communication/navigation.
2. **Minimizing Interference (Shadowing Effect)** – Ensures reception regardless of aircraft orientation.
3. **Coverage Optimization** – Some antennas are optimized for **ground communication**, others for **airborne reception**.

Question 25. What is a suppressed aerial? Discuss the installation of HF aerials on commercial aircraft.

Suppressed Aerial:

A **suppressed aerial** is an **antenna system designed to minimize radiation in specific directions** to reduce unwanted interference or signal leakage. It is commonly used in **High-Frequency (HF) communications** where directional control is essential.

Installation of HF Aerials on Commercial Aircraft:

1. **Location Considerations:**
    - Installed on the **fuselage or empennage** (tail section).
    - Placed to minimize **structural interference and aerodynamic drag**.
2. **Types of HF Aerials:**
    - **Long Wire Antennas:** Stretched along the fuselage.
    - **Probe Antennas:** Mounted on wingtips or vertical stabilizers.
    - **Loop Antennas:** Used for direction finding.
3. **Grounding and Isolation:**
    - Proper grounding prevents **electromagnetic interference (EMI)**.
    - Insulation prevents **corona discharge at high altitudes**.
4. **HF System Integration:**

- Works with **HF transceivers** to provide long-range communication.
- Used for **Air Traffic Control (ATC) and inter-aircraft communication**.

Question 26. Discuss the various satellite navigation systems operated by different countries. Compare their main features.

Navigation System	Country/Region	Orbit	Accuracy	Number of Satellites	Key Features
GPS (Global Positioning System)	USA	Medium Earth Orbit (MEO)	~3-5 meters	31	Most widely used, global coverage
GLONASS (Global Navigation Satellite System)	Russia	MEO	~5-10 meters	24	Better performance in high latitudes
Galileo	European Union	MEO	~1 meter (with high-precision service)	24	Civilian-focused, high accuracy
BeiDou (BDS)	China	MEO + Geostationary Orbit (GEO)	~2-3 meters	35	Provides global and regional services
NavIC (IRNSS)	India	GEO + Geosynchronous Orbit (GSO)	~10-20 meters	7	Regional coverage for India and surrounding areas
QZSS (Quasi-Zenith Satellite System)	Japan	GEO	~5 meters	4 (expanding)	Regional system for Japan, complements GPS

Comparison:

- **GPS, GLONASS, Galileo, and BeiDou** provide global coverage.
- **NavIC and QZSS** are regional systems tailored for specific geographical areas.
- **Galileo and BeiDou offer higher civilian accuracy** compared to GPS.
- **GLONASS performs better in high-latitude regions** (Russia, Arctic).

27. a) What is RAIM?

RAIM (Receiver Autonomous Integrity Monitoring) is a **fault-detection system** used in **GNSS receivers** to identify and correct satellite signal errors. It ensures the accuracy of positioning data by using redundant satellite signals.

RAIM Features:

- Detects **faulty satellite signals**.
- Requires **at least 5 satellites** for basic fault detection.
- Used in **aviation, maritime, and precision agriculture**.

27. b) Explain the concept of Differential Global Positioning System (DGPS).

DGPS enhances the accuracy of GPS positioning by using **ground-based reference stations** to correct satellite errors.

How DGPS Works:

1. **Reference stations** at fixed locations compare GPS data with their known positions.
2. They compute **correction signals** for errors like **ionospheric delay and satellite drift**.
3. These corrections are transmitted to **DGPS-enabled receivers** to improve location accuracy.

Accuracy Improvement:

- Standard GPS: **~3-10 meters** accuracy.
- DGPS: **~10 cm to 1 meter** accuracy.

Applications:

- **Aviation:** Aircraft precision approaches.
- **Maritime:** Ship navigation.
- **Surveying:** High-accuracy land measurements.

27. c) What is meant by 'station keeping' in relation to the GPS orbits and the CONTROL SEGMENT?

Station keeping refers to the **active management of satellite positions in orbit** to maintain precise locations for GPS operations.

Key Aspects:

- GPS satellites experience **orbital drift** due to **gravitational forces and solar radiation pressure**.
- The **Control Segment** (ground stations) monitors satellites and **sends correction commands** to adjust their position.

Methods of Station Keeping:

1. **Orbital Maneuvers:** Small thrusters adjust satellite orbits.
2. **Attitude Control:** Ensures correct orientation for signal transmission.
3. **Clock Corrections:** Keeps atomic clocks synchronized for precise timing.

Importance in GPS:

- Ensures **accuracy of navigation signals**.
- Prevents satellite **deviation from optimal orbit**.
- Maintains **global coverage and reliability**.

- END -