PAN AFRICA CHRISTIAN UNIVERSITY
Where Leaders are Made

UNIVERSITY EXAMINATIONS: 2025/2026

EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE IN INFORMATION TECHNOLOGY

BSIT306

DISTRIBUTED SYSTEMS

END TERM EXAMINATION

DATE: WEDNESDAY 29TH JULY, 2026 **TIME: 3 HOURS**

INSTRUCTIONS: Question One is Compulsory, Choose Three Other Questions

SECTION A (COMPULSORY)

QUESTION ONE (15 Marks) Compulsory

"AfyaSync" is a country-wide, real-time distributed health management platform designed for Kenya. It connects local clinic mobile apps (Edge/IoT devices), regional hospital microservices, and a centralized government analytics cloud. The platform must handle high-volume event streaming (like immediate disease outbreak alerts), guarantee high availability despite unstable rural networks, maintain chronological ordering of patient logs, and secure highly sensitive medical records.

a) Design a hybrid communication and architectural blueprint for AfyaSync. Contrast where you would use microservices versus an Edge/IoT architecture, and justify where to implement Message-Oriented Middleware (Pub/Sub) versus RESTful APIs to handle real-time medical alerting **(5 Marks).**

b) Because rural networks frequently drop, explain how you would apply the CAP Theorem to design AfyaSync's distributed data store. Choose between strong or eventual consistency models, and propose a specific clock synchronization algorithm (e.g., Lamport or Vector Clocks) to accurately order events when nodes are disconnected **(5 Marks).**

c) Formulate a comprehensive security and resilience plan for this healthcare infrastructure. Detail how a zero-trust security model would protect cross-border node communication, and evaluate how the system can achieve consensus and fault tolerance using the Raft or Paxos algorithm when regional data centers fail **(5 Marks).**

SECTION B: (ANSWER ANY THREE (3) QUESTIONS IN THIS SECTION)

QUESTION TWO (15 marks)

A financial institution is migrating its legacy monolithic banking platform into a highly scalable distributed system to manage millions of concurrent mobile transactions.

a) Analyze the core architectural challenges (e.g., latency, partial failures, scalability) when transitioning this legacy bank from a centralized setup to a **microservices-based architecture** **(7 Marks).**

b) Design a transaction processing pipeline using **Message-Oriented Middleware (MOM)** with message queues. Contrast its behavior and benefits against synchronous **Remote Procedure Calls (RPC)** during intense end-of-month transaction spikes **(8 Marks).**

QUESTION THREE (15 marks)

In a decentralized multi-player gaming environment hosted across multiple independent cloud servers, maintaining a single source of truth for global states (such as player leaderboard claims and resource ownership) is critical.

a) Apply **Lamport Clocks** or **Vector Clocks** to resolve a conflicting scenario where two players claim to have acquired the exact same rare in-game item simultaneously across different network nodes. Provide a conceptual trace of how logical clocks resolve the concurrency **(8 Marks).**

b) Evaluate the operational efficiency and failure handling of the **Bully Algorithm** versus the **Ring Algorithm** when selecting a new primary coordinator node after an active coordinator suddenly crashes **(7 Marks).**

QUESTION FOUR (15 marks)

An e-commerce platform is building a global shopping cart system and product inventory database that operates across several continents.

a) Using the **CAP Theorem** as a framework, analyze why a distributed data store like **Cassandra** is typically configured for eventual consistency for shopping carts, whereas a system like **Redis** might be preferred for high-speed local caching **(8 Marks).**

b) Formulate an operational scenario where **causal consistency** is the minimum acceptable model required for user interactions (such as product review threads), and contrast it with the performance penalties of enforcing **strong consistency** **(7 Marks).**

QUESTION FIVE (15 marks)

A distributed cloud file storage system must guarantee high reliability (99.999% uptime) even if underlying physical hard drives, network switches, or entire server racks experience routine hardware failures.

a) Examine how the system can utilize a combination of **passive redundancy (replication)** and **checkpointing** to ensure zero data loss and fast recovery states when a storage node unexpectedly loses power **(7 Marks).**

b) Critique the implementation of the **Raft Consensus Algorithm** in managing log replication across five nodes. Diagram or outline step-by-step how the cluster safely commits a write operation during a temporary split-brain network partition **(8 Marks).**

QUESTION SIX (15 marks)

A logistics multinational company is building an automated supply-chain tracking system that deploys IoT sensors on cargo fleets, uses edge nodes at shipping ports, and processes long-term data on public clouds.

a) Formulate a comprehensive **Zero-Trust Security Model** for this supply chain. Detail how mutual authentication (mTLS) and token-based authorization protect data moving dynamically from a vulnerable mobile IoT edge sensor up to the cloud core **(8 Marks).**

b) Compare the technical advantages, resource limitations, and ideal use cases of hosting application workloads across **Edge Computing** architectures versus traditional centralized **Cloud Computing service models (IaaS/PaaS/SaaS)** for real-time fleet tracking **(7 Marks).**