# Day 2- Task Sheet

**Topics:**

1. **Quantum Teleportation & Superdense Coding (Qiskit ≥ 1.0)**
2. **Quantum Key Distribution Using BB84 Protocol (With and Without Eavesdropper) (Qiskit ≥ 1.0)**
3. **Quantum Anomaly Detection**

**Description:**

This worksheet guides students through

- implementing two foundational quantum communication protocols step by step: Quantum Teleportation and Superdense Coding. Each task allows students to reason about quantum information transfer and the use of entanglement in efficient communication.
- implementing quantum key distribution (QKD) using the BB84 protocol (with an eavesdropper). Each task allows students to know about secure quantum key distribution and how to detect interception by a third person.
- Implementing anomaly detection with quantum fundamentals.

**Requirement:**

**Part A — Quantum Teleportation**
Objective: Teleport an arbitrary one-qubit state from Alice to Bob using a shared Bell pair and two classical bits.

• Prepare a 3-qubit circuit (q0: message, q1: Alice, q2: Bob).

• Create entanglement between q1 and q2 using H and CX gates.

• Apply rotations (RY, RZ) to encode an arbitrary message state on q0.

• Perform Bell measurement on q0 and q1 (CX + H + measure).

• Apply classical corrections (Z and X gates) on q2 depending on the measured bits.

• Run the circuit and visualize the state using a simulator (e.g., AerSimulator).

• Extension: Compute the fidelity between original and teleported states using the density matrix formalism.

**Sub-task 1 – Vary the Input State**

- Change the rotation angles in qc.ry(θ,q0) and qc.rz(φ,q0).

- Observe how the output on Bob’s qubit changes after correction.
- Record whether fidelity remains ≈ 1.0.

Question: Does teleportation depend on what state Alice starts with?

**Sub-task 2 – Noise and Fidelity Check**

- Add a simple depolarising noise model to the simulator.
- Compute teleportation fidelity as state_fidelity($\rho_2$, ψ_ideal).
- Plot fidelity versus noise probability.

Question: Which gates (1-qubit or 2-qubit) cause the largest drop?

**Sub-task 3 – Measurement Basis Exploration**

- Measure Bob’s qubit in both Z and X bases.
- Compare measurement statistics.

Question: Why does the X-basis reveal phase information?

**Sub-task 4 – Classical Communication Delay**

- Comment out the correction gates and run again.
- Show how Bob’s uncorrected state differs.

Question: Why are classical bits essential before Bob can recover the state?

**Sub-task 5 – Resource Counting**

- Determine how many qubits, entangled pairs, and classical bits are required to teleport:
  - 1 qubit
  - 2 qubits
  - n qubits

Question: How does resource cost scale, and why can’t we “clone” instead of teleport?

**Part B — Superdense Coding**

Objective: Transmit two classical bits using only one qubit when Alice and Bob share an entangled pair.

• Create a 2-qubit circuit (q0: Alice, q1: Bob).

• Generate a Bell pair between q0 and q1 using H and CX gates.

• Encode one of four possible 2-bit messages by applying I, X, Z, or XZ to q0.

• Perform Bell-basis decoding at Bob’s side using CX and H gates followed by measurement.

• Compare the measured 2-bit outcome to verify correct decoding.

• Extension: Introduce a simple depolarizing noise model and observe how message accuracy changes.

**Sub-task – Connection to Superdense Coding**

- Review how superdense coding uses the same Bell pair in the opposite direction.
- Identify the symmetry between teleportation (send 1 qubit → 2 bits) and superdense coding (send 1 qubit ⇐ 2 bits).

**Part C — Implementation of BB84 Protocol (With Interception)**

Objective: Securely distribute keys used to encrypt and decrypt messages using quantum key distribution.

• Prepare n qubits to represent Alice's message bits.

• Generate random bits and bases for Alice, Eve, and Bob (0 = Z-basis, 1 = X-basis).

• For each qubit:

- Encode Alice's bit in the chosen basis using X and H gates.
- Eve intercepts and measures in her basis, then resends a qubit accordingly.
- Bob measures the received qubit in his chosen basis.

• Sift the key: keep only the bits where Alice and Bob used the same basis.

• Compute the Quantum Bit Error Rate (QBER) as the fraction of mismatched bits in the sifted key.

• Print: Alice's bits and bases, Eve's bases, Bob's bases and results, sifted key, and QBER.

• Extension:

- Vary the number of qubits (n) and observe how QBER changes.
- Try running the simulation **without Eve** and compare the results.

**Part D — Implementation of Anomaly Detection in Qiskit.**

Objective: Perform anomaly detection over network connectivity using Qiskit.

1. Download the KDD Cup 1999 (KDD99) intrusion detection dataset:
2. Data Cleaning & Preprocessing
   - Load the dataset using Python.
   - Take 100 samples only.
   - Handle missing values.
   - Encode categorical features (e.g., protocol type, service, flag) using LabelEncoder or OneHotEncoder.
   - Normalize or standardize the numerical features.
   - Split the dataset into training and testing sets.
3. Model Training

   3.1 Classical Model (SVC)

      Import and train a Support Vector Classifier (SVC) from sklearn.svm.

      Tune hyperparameters (kernel, C, gamma) as needed.

      Record model training time and accuracy.

   3.2 Quantum Model (QSVC)

      Use Qiskit to implement a Quantum Support Vector Classifier (QSVC).

      Perform data encoding (feature mapping into quantum states):

      Use classical-to-quantum encoders such as ZFeatureMap/ZZFeatureMap/PauliFeatureMap (Qiskit)

      Choose a simple quantum kernel or construct a custom circuit.

4. Evaluate using metrics like accuracy, precision, recall and F1-score. Also, visualise accuracies over iterations (plot graphs).

**Reflection**

• Compare what is transmitted in teleportation vs. superdense coding.

• Explain one real-world advantage of quantum communication over classical.

• Suggest one source of error and a method to mitigate it (e.g., purification, error correction).

• Encode classical bits as qubits using Z and X bases.

• Simulate quantum key distribution with an eavesdropper.

• Understand how measurement in different bases affects qubit correlation.

## Submission Details:

1. You must ensure that all your project files used for this task sit in a directory
2. All files are required to be uploaded
3. Please make sure that teacher have access to the folder.