Part B: Conceptual Questions (2 marks)

1. Explain what happens if an eavesdropper intercepts the qubit sent from Alice to Bob?

Answer:

If an eavesdropper, say Eve, tries to intercept the qubit traveling from Alice to Bob, she won't actually learn anything useful about the 2-bit message. That's because the qubit being sent is just one half of an entangled Bell pair. On its own, that qubit is in a maximally mixed state, its density matrix is just 1/2, so it contains no information at all, no matter what message Alice intended to send.

If Eve goes ahead and measures the qubit anyway, she ends up destroying the entanglement. This introduces errors when Bob tries to decode the message later on. The whole protocol falls apart in that case, and Bob won't be able to recover the original message correctly. The security here comes from the fact that the encoding only makes sense when both entangled qubits are brought together and measured in the Bell basis.

2. Give one application or implication of superdense coding.

Answer:

Superdense coding lets us send two classical bits using just one qubit, effectively doubling the communication capacity of a quantum channel. That's a pretty big deal for quantum networks where qubit transmission is limited and valuable. In practice, this could be used in a future quantum internet, nodes could share entanglement ahead of time during quiet periods, and then later use superdense coding to send classical messages at twice the usual rate. That means you'd need fewer qubit transmissions for the same amount of classical information, which helps reduce bandwidth usage in hybrid quantum-classical systems.

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Quantum Computing Assignment 1 – Part B