Introduction to Quantum Programming and Semantics: summary

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Quantum Programming

"Not yet one platform to rule them all"

- OpenQASM: open standard, very basic type system, have to define basic gates
- Qiskit: circuit description, simulation, hardware backend
- Quipper: Haskell, higher-order, data types, recursion, circuit-generating
- Q#: QRAM model, measurement for control flow, dot.net/Azure
- Silq: uncomputation, linear type system, qfree
- PyZX: Python, rewriting, optimisation

Categories

"Morphisms are more important than objects"

- **Set**, **Rel**, **FHilb**
- Universal properties: products

Monoidal categories

"Can compose morphisms in sequence and in parallel"

- Coherence theorem
- Graphical calculus: isotopy
- Braiding, symmetry

Scalars

"Monoidal categories replicate linear algebra features"

- Scalars commute
- Scalar multiplication
- Dagger categories
- Way of the dagger

Dual objects

"Dual objects model maximally entangled states"

- Definition: cup, cap, snake equation
- Names, conames
- Transpose morphisms
- Traces and dimension
- Teleportation, one-time pad encryption

Monoids and comonoids

"Comonoids model copying"

- Monoid: unit and multiplication
- Monoids embed into pair of pants
- No uniform cloning or deleting
- When tensor products are products

Frobenius structures

"Classical structures model classical data"

- Frobenius law: dagger and closure
- Spider theorem
- Phases
- In **FHilb**: matrix algebras and orthogonal bases
- in **Rel**: groupoids

Complementarity

"Complementary Frobenius structures are maximally incompatible"

- Mutually unbiased bases
- ZX calculus
- Oracles
- Deutsch-Jozsa algorithm

ZX calculus

"Axiomatise qubit computation graphically"

- Sound and complete
- Approximately universal
- Rewriting system may be automated
- Quantum circuit simplification

Exam

- Answer two out of three questions
- If can't solve subquestion, assume answer and move on

Good luck!