Quantum Curriculum in the US:
Quantifying the instructional time, content taught, and paradigms used

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Q1: How many courses on quantum concepts are physics students required to complete to be awarded a four-year degree?

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190 institutions with graduate degrees in physics offered [1]

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190 institutions with graduate degrees in physics offered [1]

188 institutions offer a 4-year degree in physics

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190 institutions with graduate degrees in physics offered [1]

188 institutions offer a 4-year degree in physics

74.5% R1 Institutions
22.3% R2 Institutions
6 institutions not classified [2]

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190 institutions with graduate degrees in physics offered [1]

188 institutions offer a 4-year degree in physics

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69.7% Public
30.3% Private [2]

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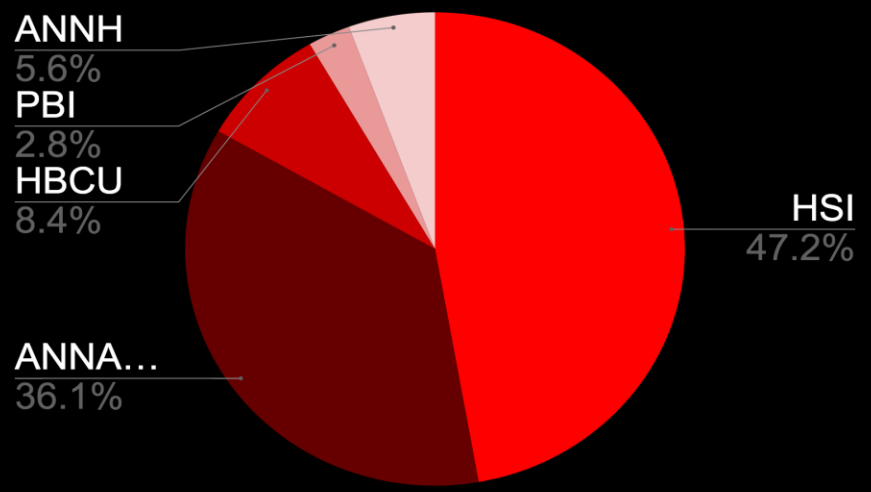
16.5% Minority Serving Institutions [3]



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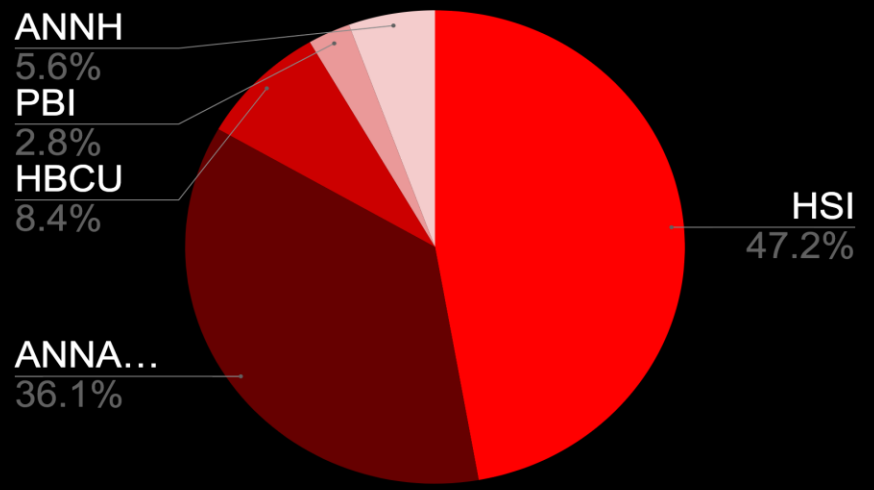
56.7% Physics Bachelors in 2021-22 [4]



Degree Requirements

Required Courses 37 - 45 Total Credits

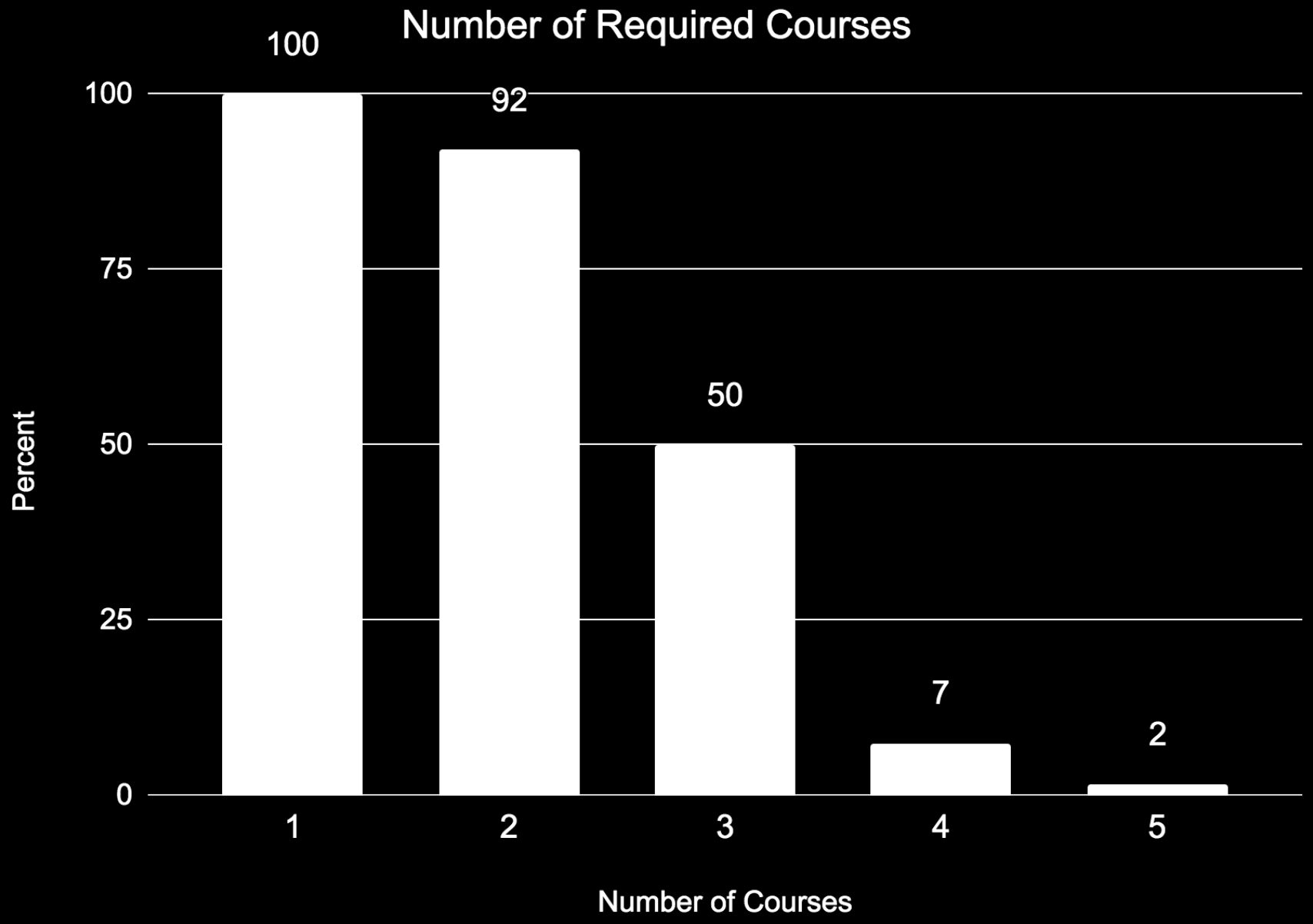
- Complete all of the following
  Core Physics Courses
  - Complete all of the following
    - Earned a minimum grade of C- in each of the following:
      - PHYS2210 - Physics for Scientists and Engineers I (4)
      - PHYS2215 - Physics Laboratory for Scientists and Engineers I (1)
      - PHYS3980 - Undergraduate Seminar II (1)
    - Earned a minimum grade of C- in each of the following:
      - PHYS2220 - Physics for Scientists and Engineers II (4)
      - PHYS2225 - Physics Laboratory for Scientists and Engineers II (1)
    - Earned a minimum grade of C- in each of the following:
      - PHYS1980 - Undergraduate Seminar I (1)
      - PHYS2235 - Computational Laboratory for Physicists (1)
      - PHYS2710 - Physics III -- Modern Physics and Thermodynamics (4)
    - Earned a minimum grade of C- in each of the following:
      - PHYS3010 - Physics IV- Intermediate Mechanics with Special Relativity (4)
    - Earned a minimum grade of C- in each of the following:
      - PHYS4010 - Physics V- Electromagnetism and Quantum Mechanics (4)

PHYS2710 Physics III -- Modern Physics and Thermodynamics (4)

This is the third course in the core physics sequence and focuses on physics largely discovered, and applied, in the early part of the 20th century. Topics include waves, quantum mechanics, atomic physics, nuclear physics, thermodynamics, and statistical ...

PHYS4010 Physics V- Electromagnetism and Quantum Mechanics (4)

This class is a mixture of electromagnetism and quantum mechanics. It will be taught at an intermediate level. For electromagnetism, topics include electrostatics, magnetostatics and electrodynamics. For quantum mechanics, topics ...



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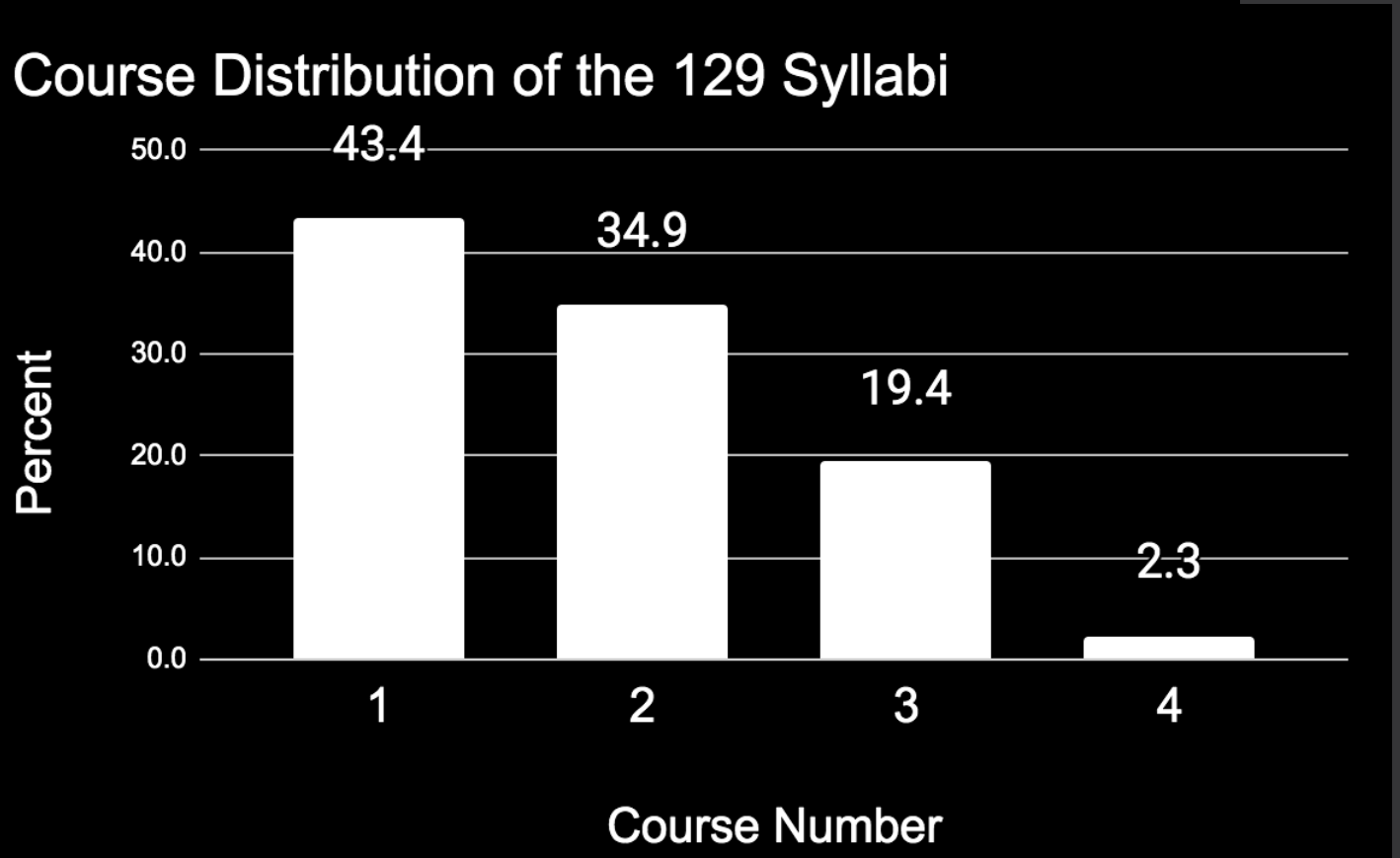
Q2: How many instructional hours on quantum concepts are physics students required to take to graduate with a four-year degree?

188 institutions offer a 4-year degree in physics

Obtained syllabi from all required courses with quantum concepts from 56 institutions

129 syllabi
51.2% obtained publicly
48.8% obtained from private correspondence



Lecture needs to cover one of the following topics to be coded as covering quantum concepts:

Schrödinger
Schrödinger Equation
Photoelectric Effect
Wave-Particle Duality
Operators
Eigenvalues
Tunneling/Reflection
Stern-Gerlach Experiment
Dirac Notation
States
Quantum Measurement
Expectation Value
Uncertainty
Superposition
Mixed States
Quantization
Fermi's Golden Rule

Photons
Pauli's Exclusion Principle
Square Well
Identical Particles
Matter Waves
Frank Hertz Experiment
Wave Mechanics
Wave Functions
Wave Properties of Particles
Particle Properties of Waves
de Broglie Hypothesis
Quantum Theory of Light
Blackbody Radiation
Planck's Postulate
Spin

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Class	Date	Content
1	Aug 22nd	Introduction, Waves: Oscillations
2	24th	Waves: Traveling
3	29th	Waves: Super Position
4	31st	Thermodynamics: Work and 1st Law
5	Sept 5th	Labor Day
6	7th	Thermodynamics: Micro/Macro Connec.
7	12th	Foundations of Modern Physics
8	14th	Photoelectric Effect and Photons
9	19th	Bohr Model and Hydrogen Spectrum
10	21st	Quantization Challenging Problems
11	26th	Double Slit Exp. & Wave Functions
12	28th	Normalization and Uncertainty
13	Oct 3rd	Wave Func.: Challenging Problems
14	5th	Exam 1 Review
Recit.	*7th*	*Exam 1*
15	10th	Fall Break
16	12th	Fall Break
17	17th	QM: Schrödinger Equation
18	19th	QM: Finite Square Well, Wave Shapes
19	24th	QM: Harmonic Oscl. & Tunneling
20	26th	QM: Challenging Problems
21	31st	H atom and Electron Spin
22	Nov 2nd	Multi Electron Atoms
23	7th	Lifetime, Decay, Emissions
24	9th	Atomic Physics: Challenging Problems
25	14th	Nuclear Structure and Stability
26	16th	The Strong Force and Shell Model
27	21st	Radiation and Decay
28	23rd	Nuc. Physics: Challenging Problems
29	28th	Nuclear Science Ethics debate
30	30th	Exam 2 Review
Recit.	*Dec 2nd*	*Exam 2*
31	*5th*	*Final Exam Pt 1, Turn in Projects*
32	*Dec 7th*	*Final Exam Pt 2*

Lectures **MWF: 3:00pm – 4:20pm,**

80 minutes per lecture

15 QM Lectures

1,200 Minutes on QM concepts (20 Hours)

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Total QM Minutes in Degree for each Institution

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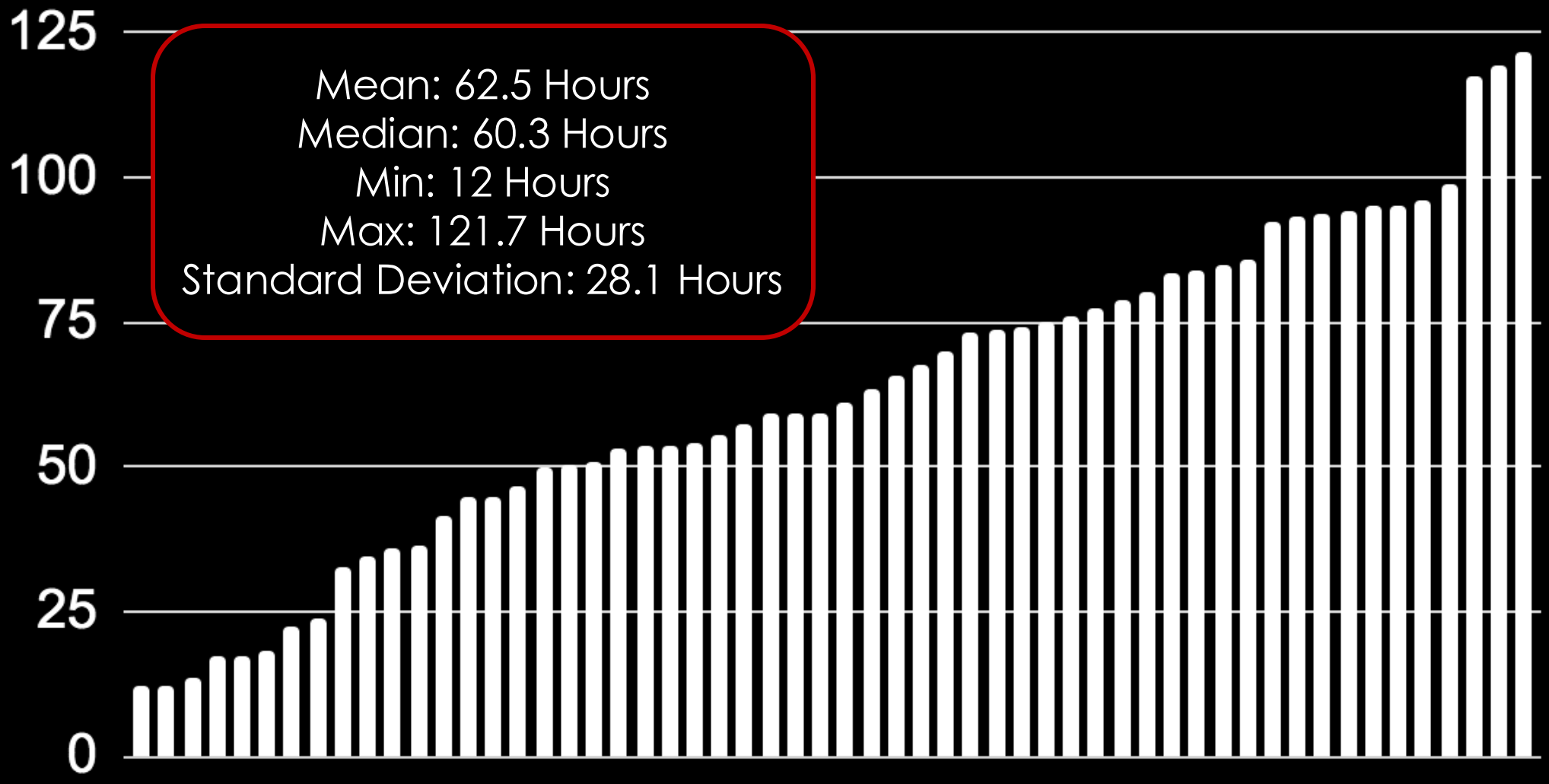

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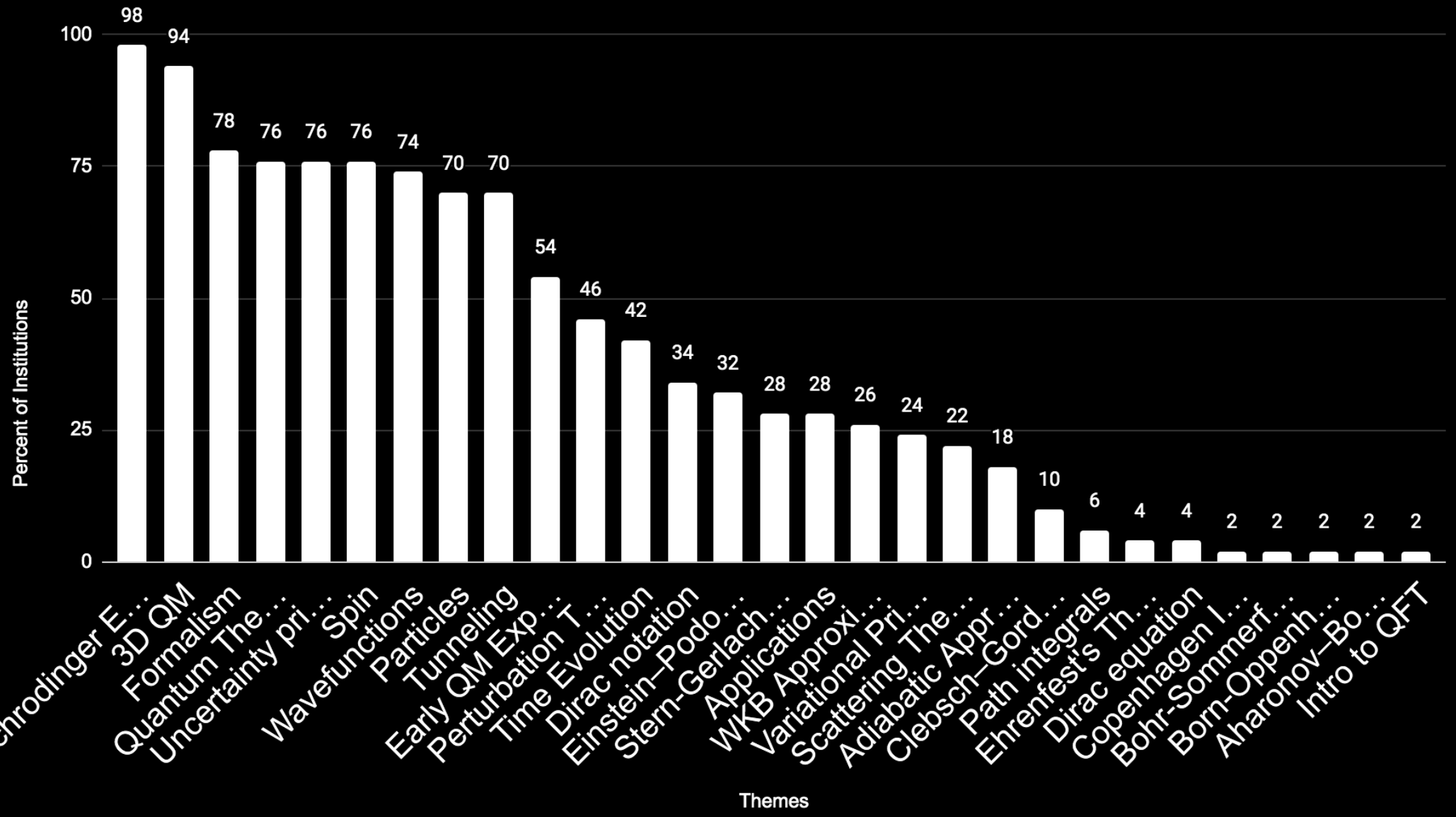
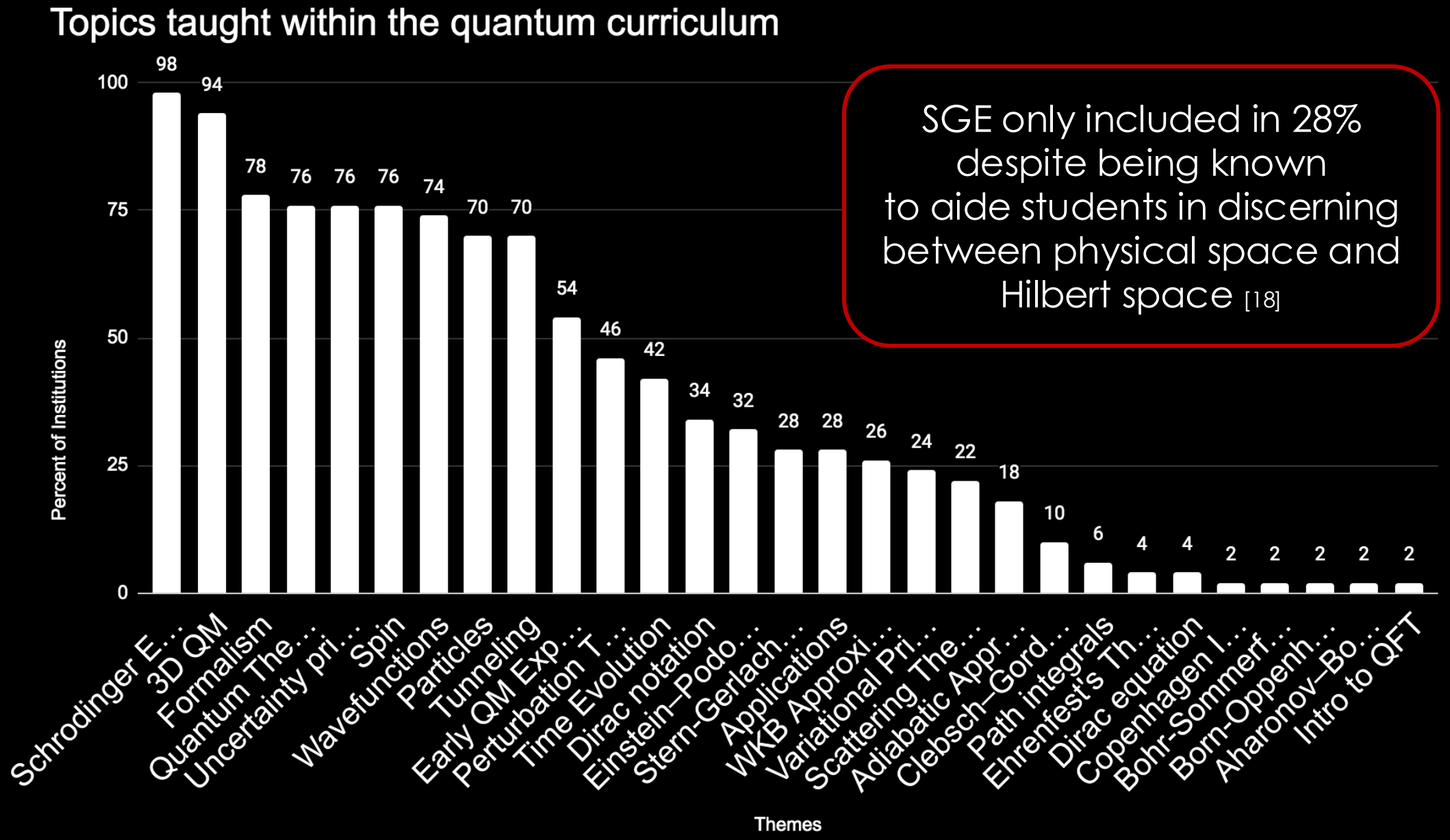
Q3: What quantum topics are students required to learn before graduation?

Topics taught within the quantum curriculum





SGE only included in 28% despite being known to aide students in discerning between physical space and Hilbert space [18]

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Q4: Are institutions utilizing a spins-first or position-first approach when teaching quantum?

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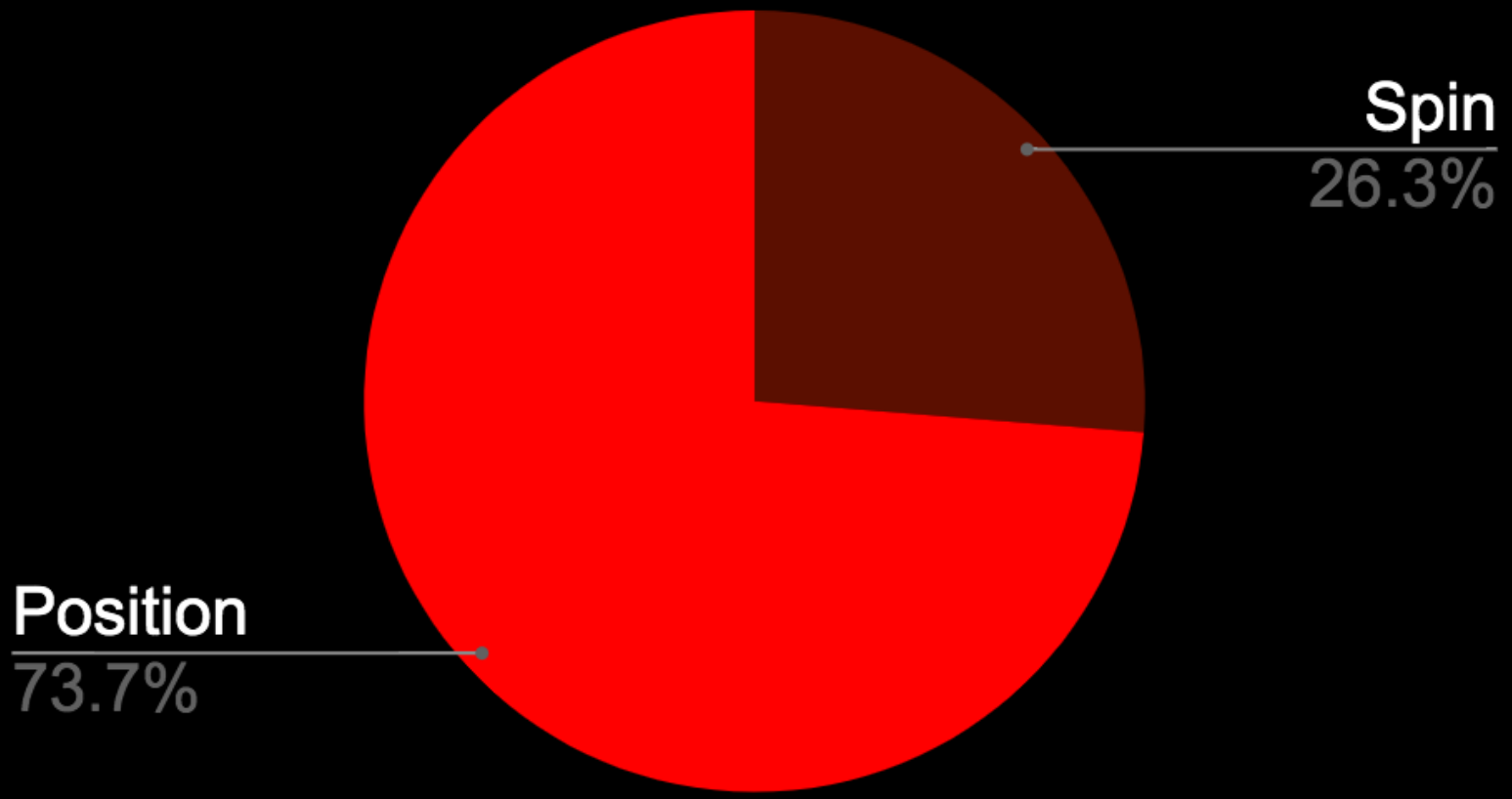
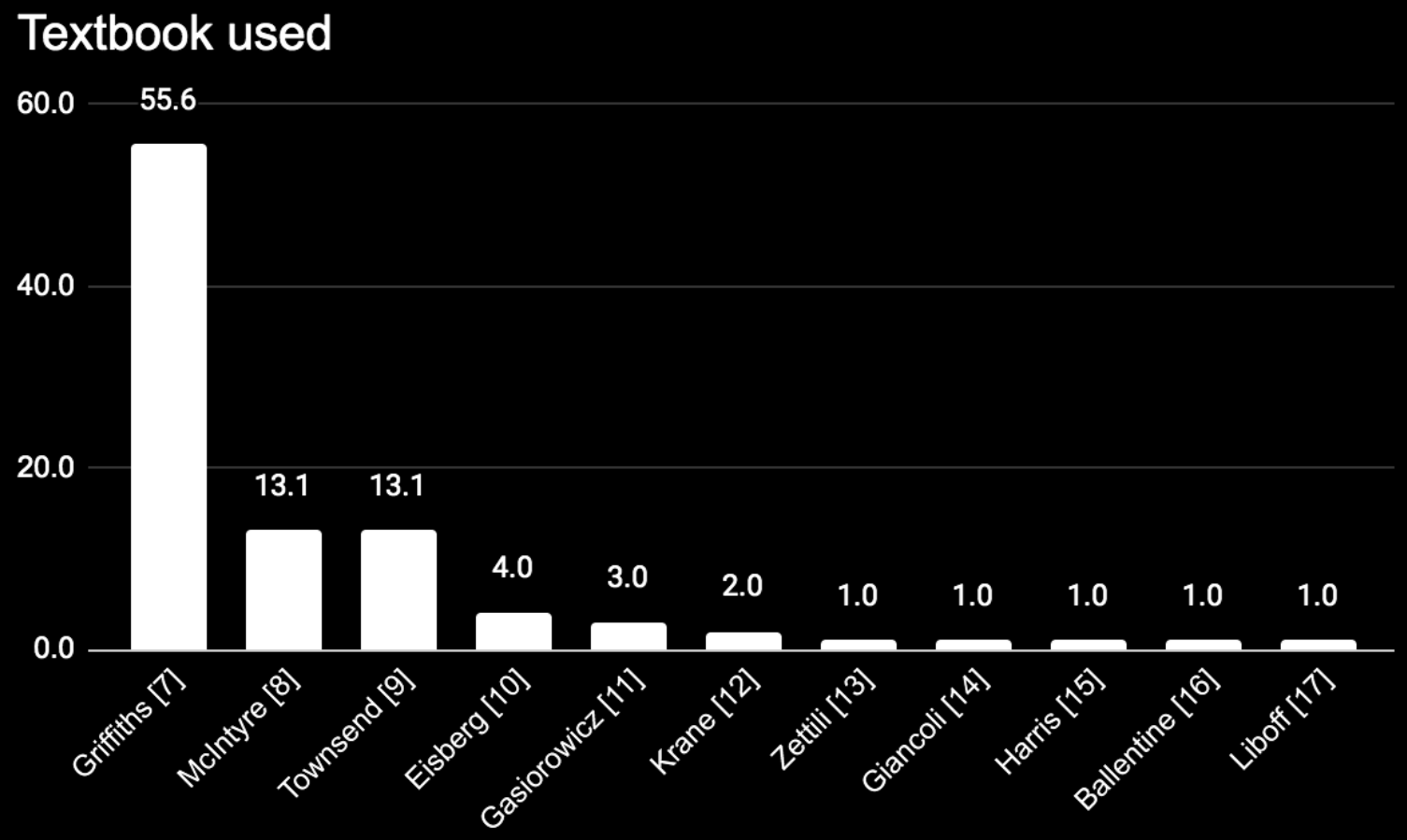
Coding used to determine spin-first vs. position-first paradigm	
Spin-First	**Position-First**
• Stern-Gerlach experiment [6] • Postulates of quantum mechanics [5, 6] • Schrödinger equation in context of spin ½ particles [5] • Matrix equations [6] • Eigenvalue equations regularly used before Schrödinger equation introduced [5] • McIntyre's textbook used [5, 8]	• Schrödinger equation introduced early on [5,6] • Schrödinger equation used in context of position space wavefunctions [5] • Differential equations [5] • Griffith's textbook used [5,7] • Time independent Schrödinger equation is first eigenvalue equation introduced [5]

Paradigm used




Textbook used
60.0
40.0
20.0
0.0
55.6
13.1
13.1
4.0
3.0
2.0
1.0
1.0
1.0
1.0
1.0
Griffiths [7]
McIntyre [8]
Townsend [9]
Eisberg [10]
Gasiorowicz [11]
Krane [12]
Zettili [13]
Giancoli [14]
Harris [15]
Ballentine [16]
Liboff [17]


position-first
spin-first
Griffiths [13]
McIntyre [14]
Townsend [21]
Eisberg & Resnick [22]
Gasiorowicz [23]
Krane [24]
Zettili [25]
Giancoli [26]
Harris [27]
Ballentine [87]
Liboff [29]
0
20
40
60
80
100

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Summary:

- **Quantum curriculum varies widely at research intensive institutions in the US**
- **Instructors still using position-first approach and focusing course on solutions to the TISE**
- **SGE not commonly introduced in undergraduate courses**

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