Characterizing the US Graduate Quantum Curriculum

Physics Education Research at The University of Utah

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90% of US physics graduate programs test student's quantum knowledge on their qualifying exams for candidacy[1].

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"Students' experiences with the [written qualifying exam] are consistent with psychological responses to traumatic events"[2]

Important that we are testing them on relevant concepts for their graduate career--

But what are we teaching them?

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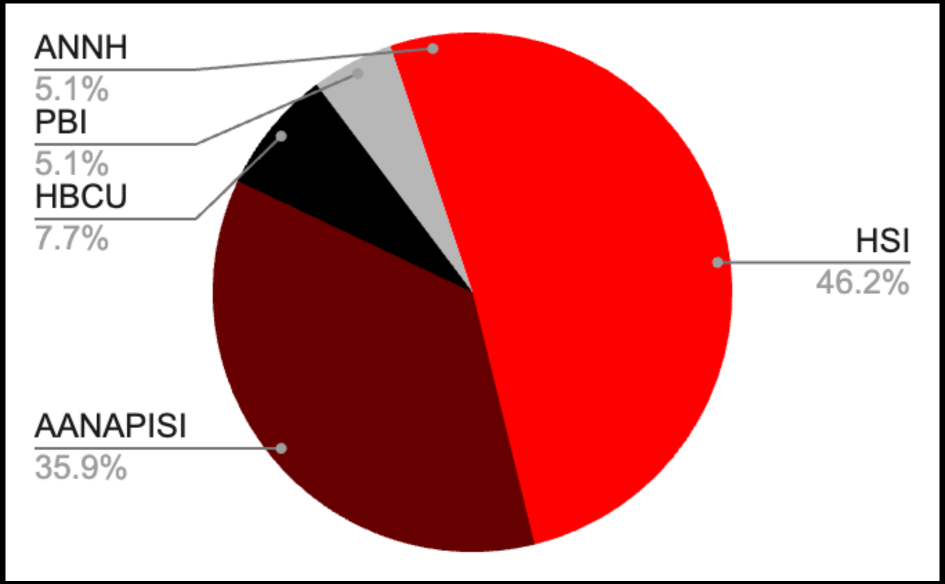
180 English-speaking institutions with doctoral degrees in physics offered + 4 additional MSI's that offer doctoral degrees for 184 institutions total

89% of PhD degrees & 53% of exiting Masters degrees awarded in 2022-23

84% of enrolled PhD graduate students and
79% of first-year graduate students in 2023-24

70% Public
76% R1

18% MSI



Course catalog data:

◇ *1st semester.* All graduate students take the same three courses during their first semester:

Classical Mechanics/E&M I (PHYS 7110) (4 credit hours),
Quantum Theory I (PHYS 7220) (4 credit hours),
Faculty Research Overview (FRO) (PHYS 7820) (1 credit hour).

These three courses add up to 9 credit hours. (International students may be required to take an additional 3-credit course in English language skills.) The final exams of Classical Mechanics/E&M I and Quantum Theory I courses form the Comprehensive Exams; see Section 3.4.1.

◇ *2nd semester & 1st summer.* In their second semester, students specialize into four separate tracks, each with two or three additional required courses:

PHYS7640
Quantum Field Theory I
Introduction to quantum field theory and second quantization. Nonrelativistic applications and quantum electrodynamics.

PHYS7650
Quantum Field Theory II
Continuation of PHYS 7640. Path integral spontaneous symmetry breaking, quantum chromodynamics and renormalization group.

PHYS7220
Quantum Theory I
Nonrelativistic and relativistic quantum theory with applications to atoms, molecules, scattering, and radiation.

PHYS7230
Quantum Theory II
Continuation of PHYS 7220.

1 core course

3 elective courses

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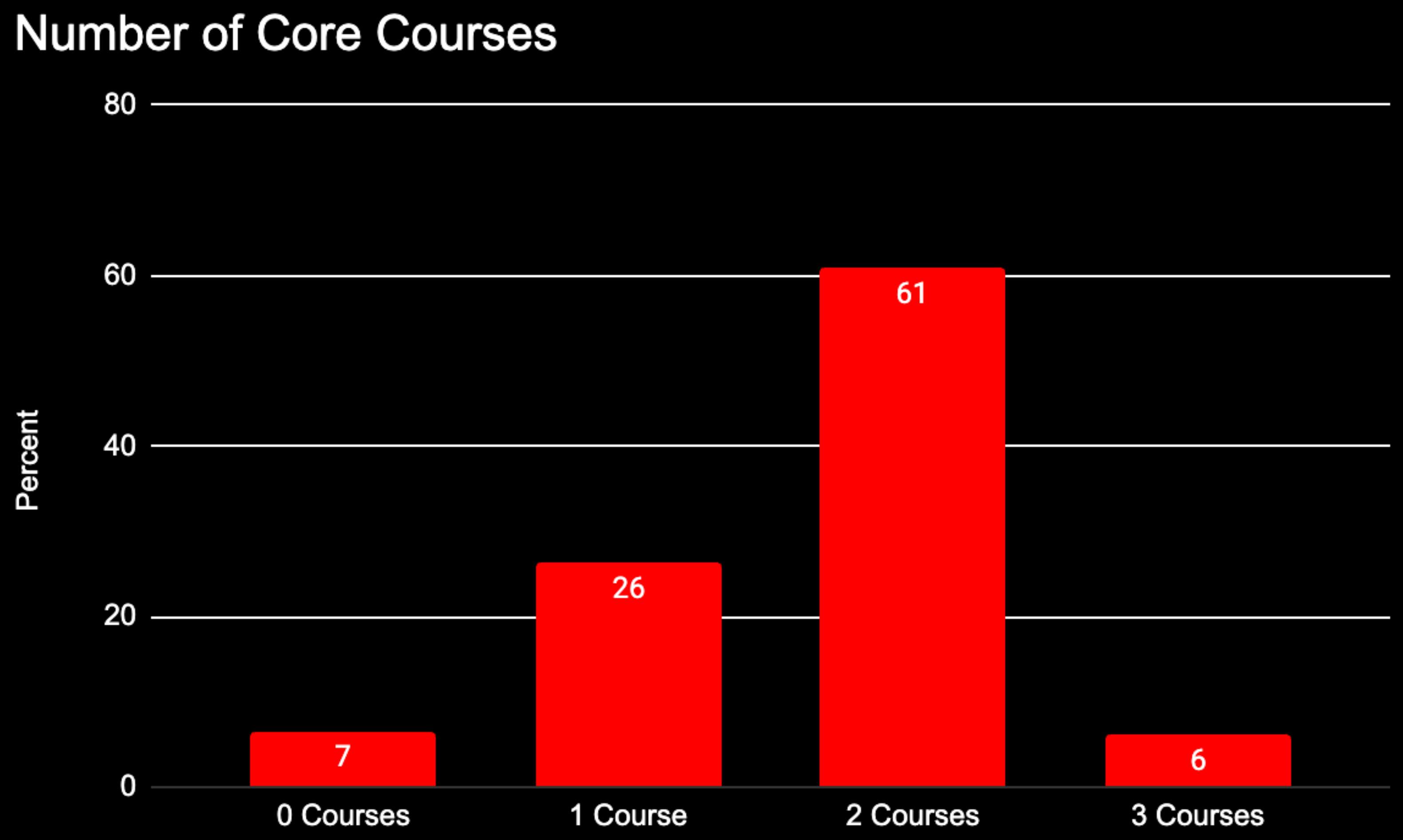
Course catalog data:



Elective catalog courses seems to be outdated/variable so will not be reporting on those numbers yet

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Preliminary Data As of March 3rd:

431 Syllabi collected

137 syllabi from core courses

294 syllabi from elective courses

26 Complete sets (syllabi from all core and elective courses collected)

78 Complete core sets (syllabi from all core courses collected)

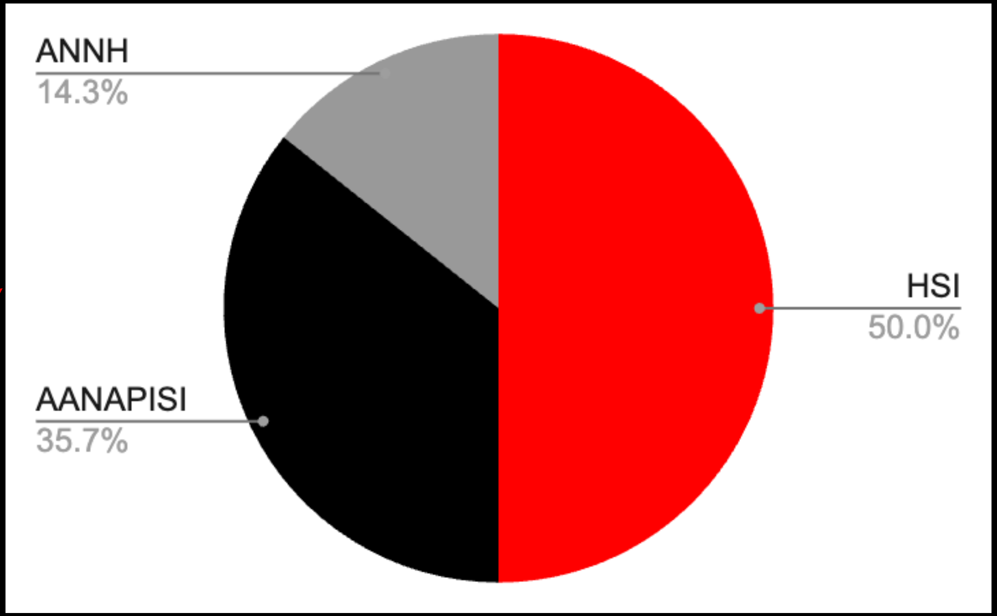
78 Institutions with core course syllabi collected

43% of PhD degrees & 25% of exiting Masters degrees awarded in 2022-23

40% of enrolled PhD graduate students and
38% of first-year graduate students in 2023-24

72% Public
78% R1

17% MSI

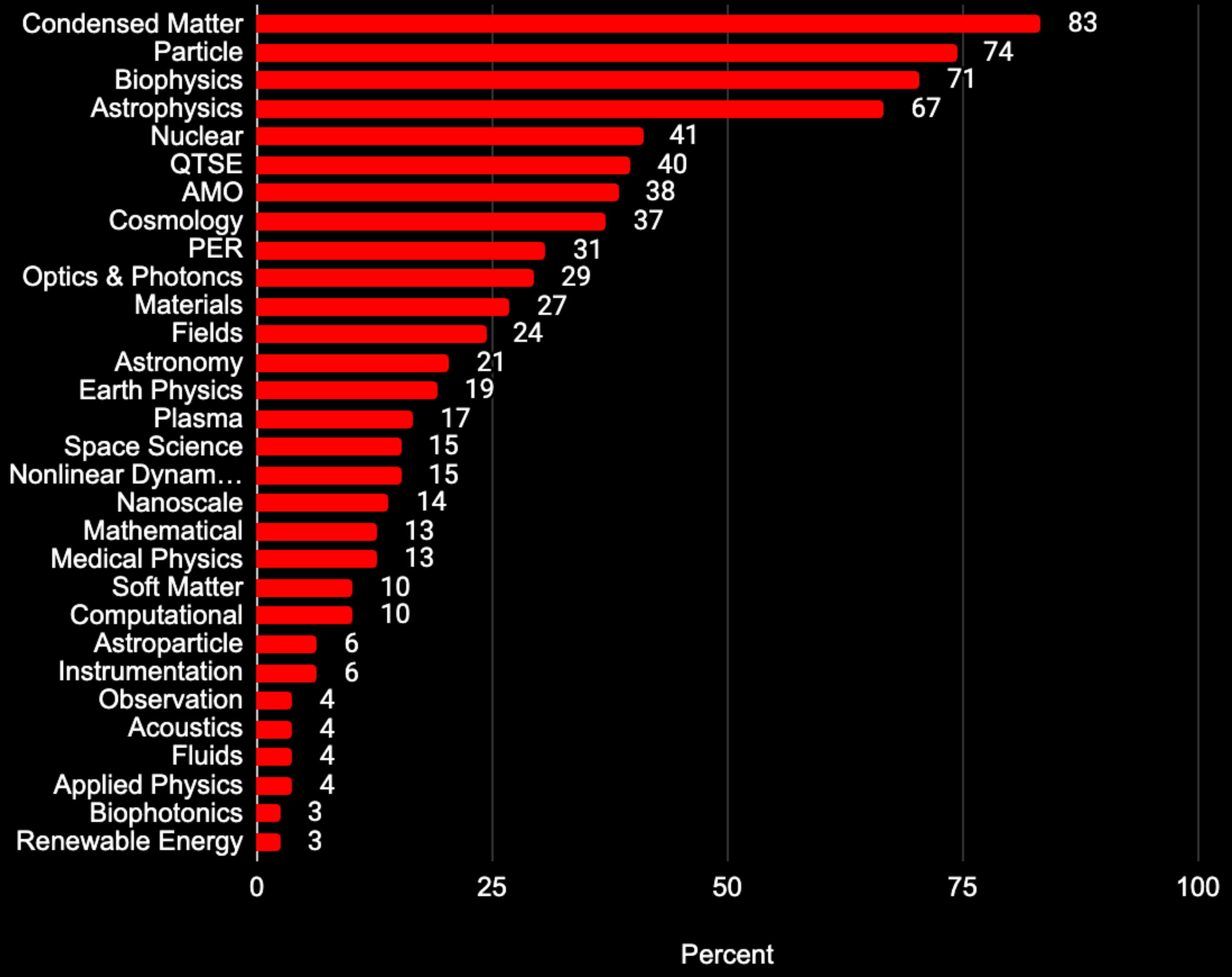


Research Fields at the 78 Institutions

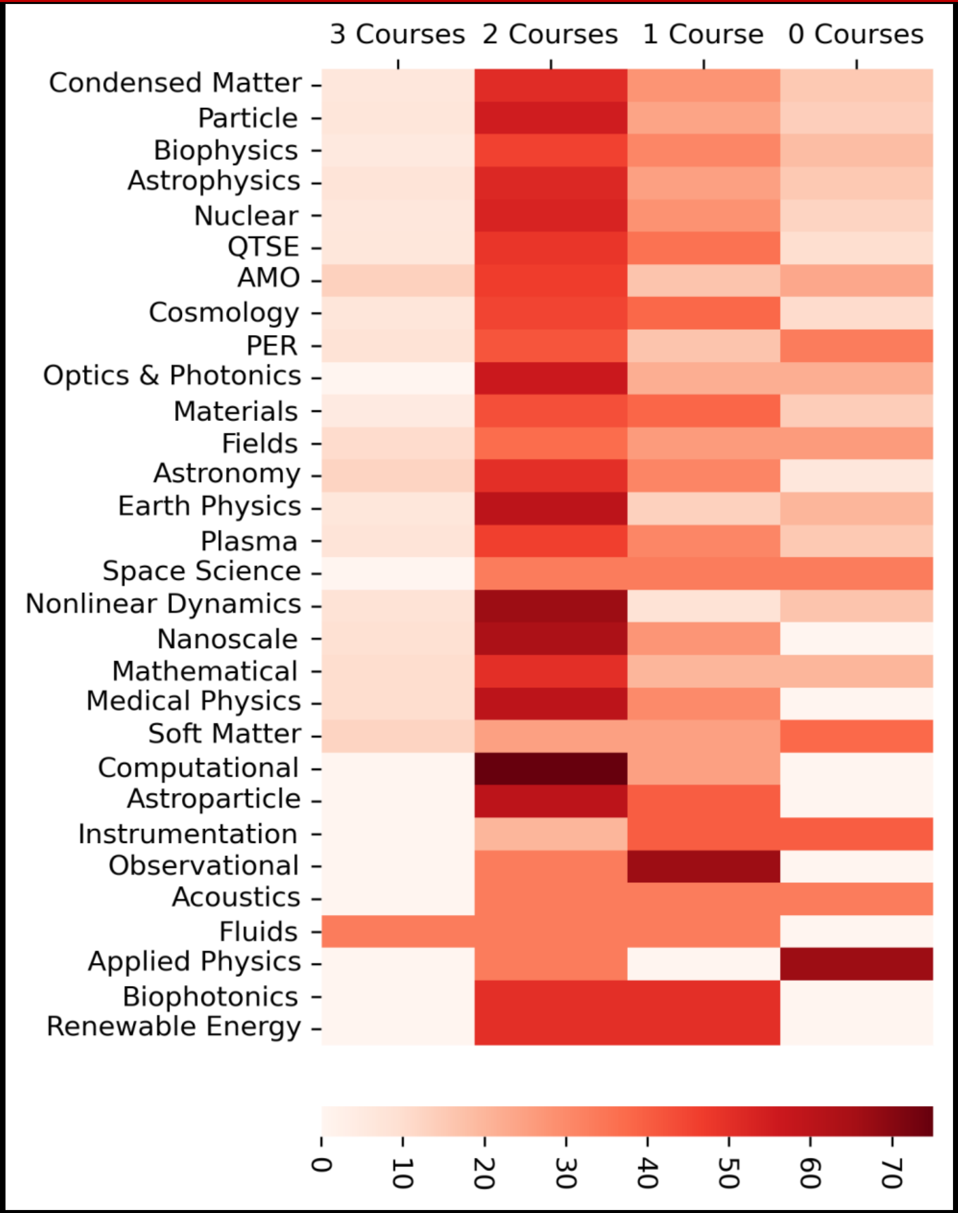
Research

- Research Overview
- Astronomy
- Biophysics
- Condensed Matter Physics
- Astroparticle Physics
- High Energy Physics
- Physics Education Research

Research Fields at the 78 Institutions



Research Fields at the 78 Institutions



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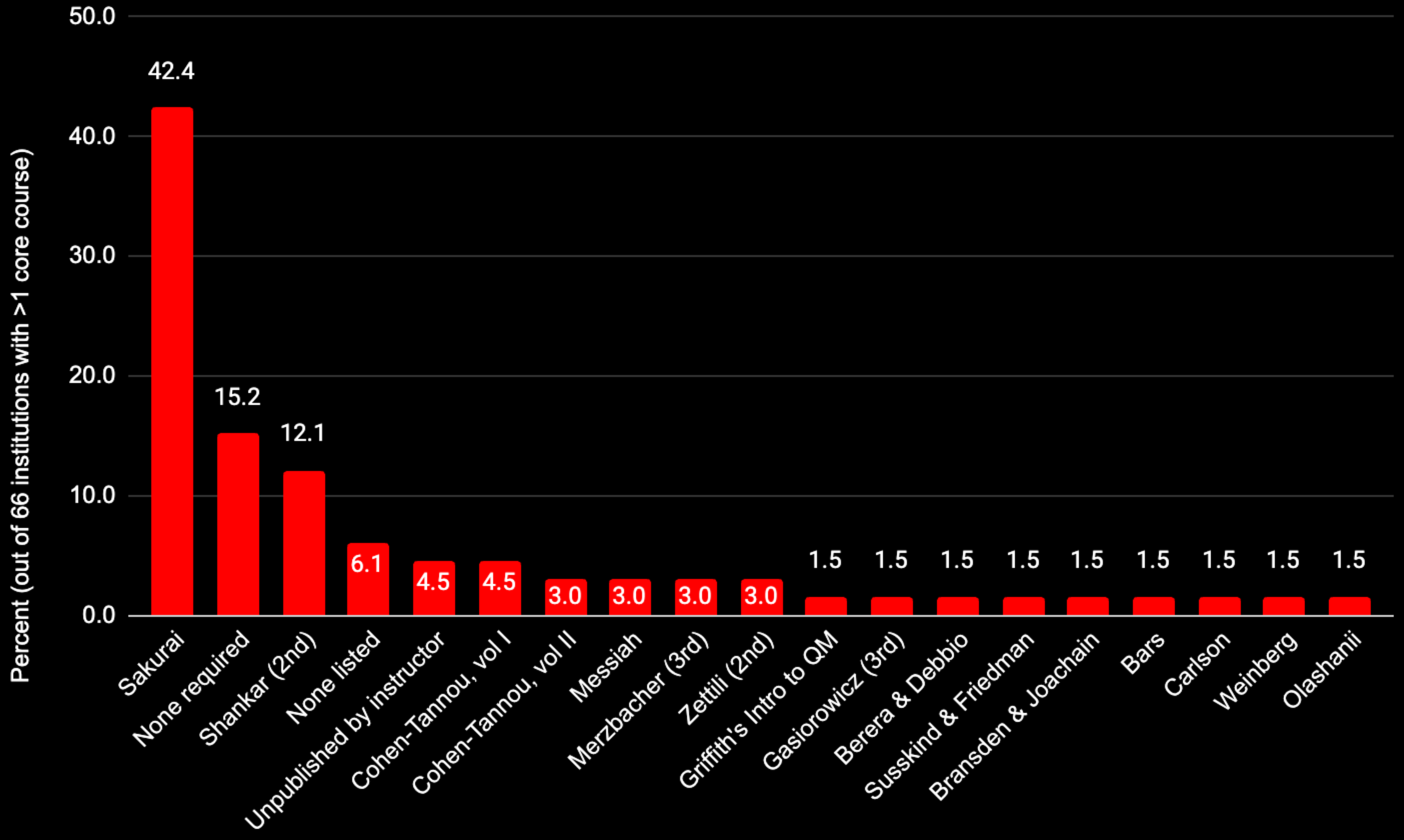
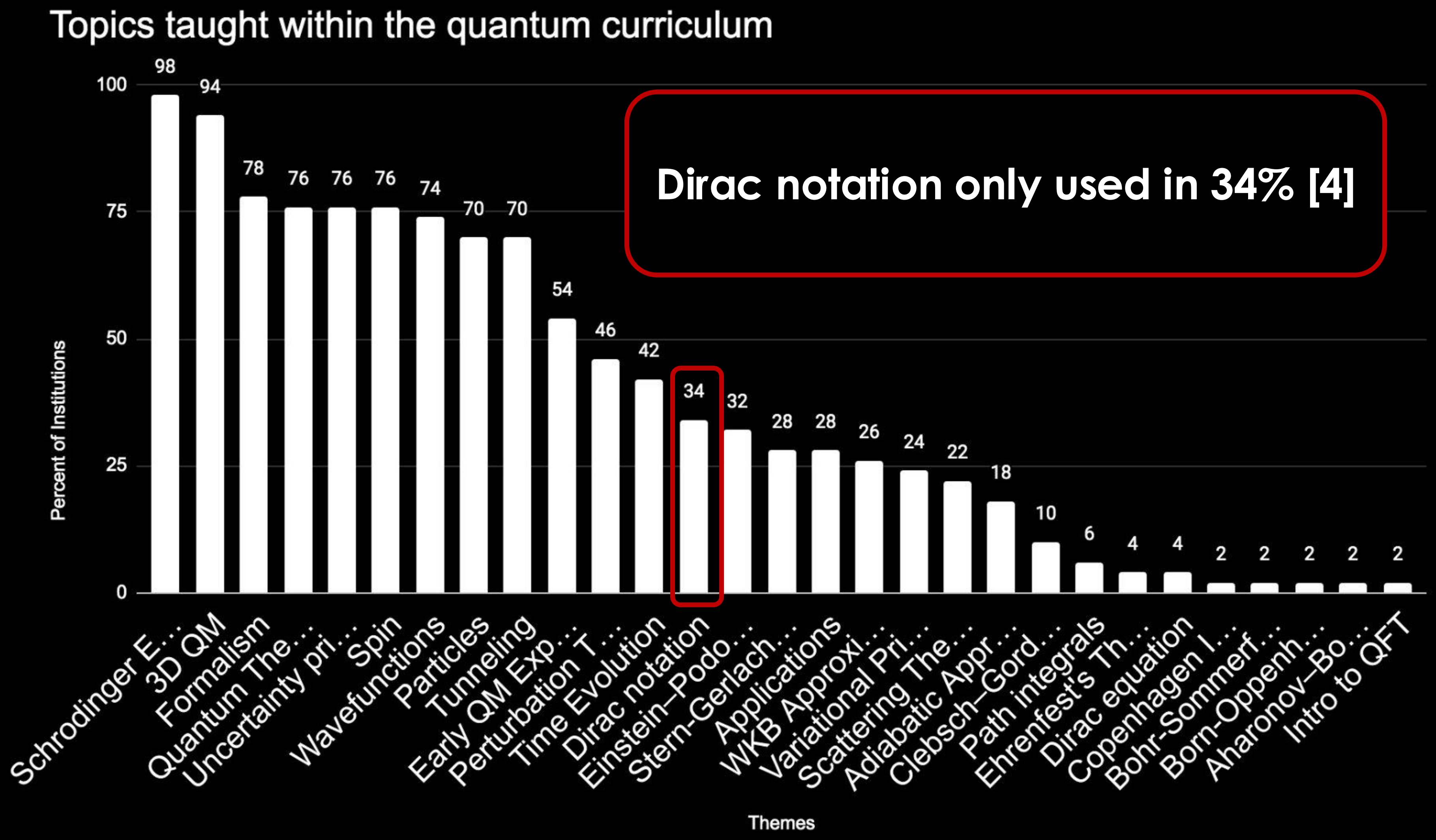
Textbooks used by 66 institutions with 1 or more core courses



Comparison to Undergraduate Curriculum

"...even graduate students do not yet have a good grasp of the [Dirac] notation" [3]



Dirac notation only used in 34% [4]

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Comparison to Undergraduate Curriculum

$$|\alpha\rangle \doteq \begin{pmatrix} \langle a^{(1)}|\alpha\rangle \\ \langle a^{(2)}|\alpha\rangle \\ \langle a^{(3)}|\alpha\rangle \\ \vdots \end{pmatrix}, \quad |\gamma\rangle \doteq \begin{pmatrix} \langle a^{(1)}|\gamma\rangle \\ \langle a^{(2)}|\gamma\rangle \\ \langle a^{(3)}|\gamma\rangle \\ \vdots \end{pmatrix}. \qquad (1.3.26)$$

Sakurai [5]

First introduction to a ket as a column matrix in Sakurai vs. McIntyre

$$|+\rangle_x \doteq \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ 1 \end{pmatrix}, \qquad (1.47)$$

$$|-\rangle_x \doteq \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ -1 \end{pmatrix} \begin{matrix} \leftarrow |+\rangle \\ \leftarrow |-\rangle \end{matrix}, \qquad (1.48)$$

$$\begin{aligned} |+\rangle &\doteq \begin{pmatrix} 1 \\ 0 \end{pmatrix} \\ |-\rangle &\doteq \begin{pmatrix} 0 \\ 1 \end{pmatrix}. \end{aligned} \qquad (1.49)$$

$$|\psi\rangle \doteq \begin{pmatrix} \langle +|\psi\rangle \\ \langle -|\psi\rangle \end{pmatrix}. \qquad (1.50)$$

McIntyre [6] has three examples before introducing arbitrary state

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Are written qualifying exams traumatic because we're testing students on notation only a third have seen before?

Is this a fair test?

If you or a colleague teaches a graduate level quantum course, please feel free to email me a copy of your syllabi.

If you have feedback or have specific graduate quantum related data you would like to see, send me an email!

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References:
[1] D. Campbell, T. Appelquist, R. Diehl, J. Fajans, J. D. Garcia, J. Gates, A. Goldman, P. Jung, and M. Paesler, Graduate Education in Physics (Report of the Task Force on Graduate Education in Physics (American Association of Physics Teachers and American Physical Society, College Park, MD, 2006).
[2] S. Basir and E. Burkholder, "Departmental case study of physics doctoral students' perspectives of written qualifying exams", Phys. Rev. Phys. Educ. Res. 20, 020123 (2024).
[3] C. Singh and E. Marshman, "Investigating student difficulties with dirac notation", in Physics education research conference 2013 (2013), pp. 345–348.
[4] Buzzell, A., Barthelemy, R., & Atherton, T. (2025). Quantum curriculum in the US: Quantifying the instructional time, content taught, and paradigms used, Physical Review Physics Education Research, 21(1), 010102.
[5] J. J. Sakurai and J. J. Napolitano, Modern quantum mechanics, 2nd (Addison Wesley, San Francisco, 2010).
[6] D. H. McIntyre, Quantum mechanics: a paradigms approach (Pearson, Boston, 2012).