Supplementary Material: Sense-making with Inscriptions in Quantum Mechanics

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1. Introduction

This document provides supporting materials for a paper submitted for review to the Physics Education Research Conference proceedings in July 2016, "Sense-making with Inscriptions in Quantum Mechanics."

The Physics Education Research Group at the University of Maryland, College Park has developed a set of curriculum materials for students learning quantum mechanics. Design choices behind the materials are driven by the goal of helping students develop heightened awareness and regulation of the different types of reasoning that they draw on when sense-making in the domain of quantum mechanics. One aspect of student sense-making that we focus on in this paper is how student reasoning interfaces with written representations.

In the paper, we analyze a short segment of video of a senior physics major working through physics problems developed by our research group. The student, pseudonym Chad, was recruited by email and offered $15 for an hour of his time. The interview took place, with the first author (Ronayne Sohr) as interviewer, in a conference room with both Chad and the interviewer seated next to each other at the end of a conference table. There were two cameras set up, one to focus on Chad's written work, and the other with a larger view: showing the interviewer, Chad and his written work between them. The interviewer prompted Chad for some background information, revealing that he had completed a two-semester, upper-level quantum mechanics course for physics majors the previous semester.

The PERC Proceedings paper provides a fine-grained analysis of a short bit of Chad's sense-making, showing Chad's sense-making as deeply entwined with his use of various inscriptions or written representations. We see a reflexive interplay between the inscriptional system that Chad develops and the substance of his sense-making, such that his sense-making shapes, and is shaped by, the inscriptions he draws on. Additionally, we see Chad drawing on two canonical representational forms: 1) the wavefunctions of the particle in a box, shown in single box with vertical separation, 2) a wavefunction demonstrating tunneling in a finite potential well. Chad uses these canonical forms to give additional meaning to a non-standard form of his creation: the first two allowed states of an infinite particle in a box with a slanted bottom.

The following pages contain a scanned copy of Chad's written work, with the different inscriptions numbered. The next page contains the transcript of the clip of video data analyzed in the paper

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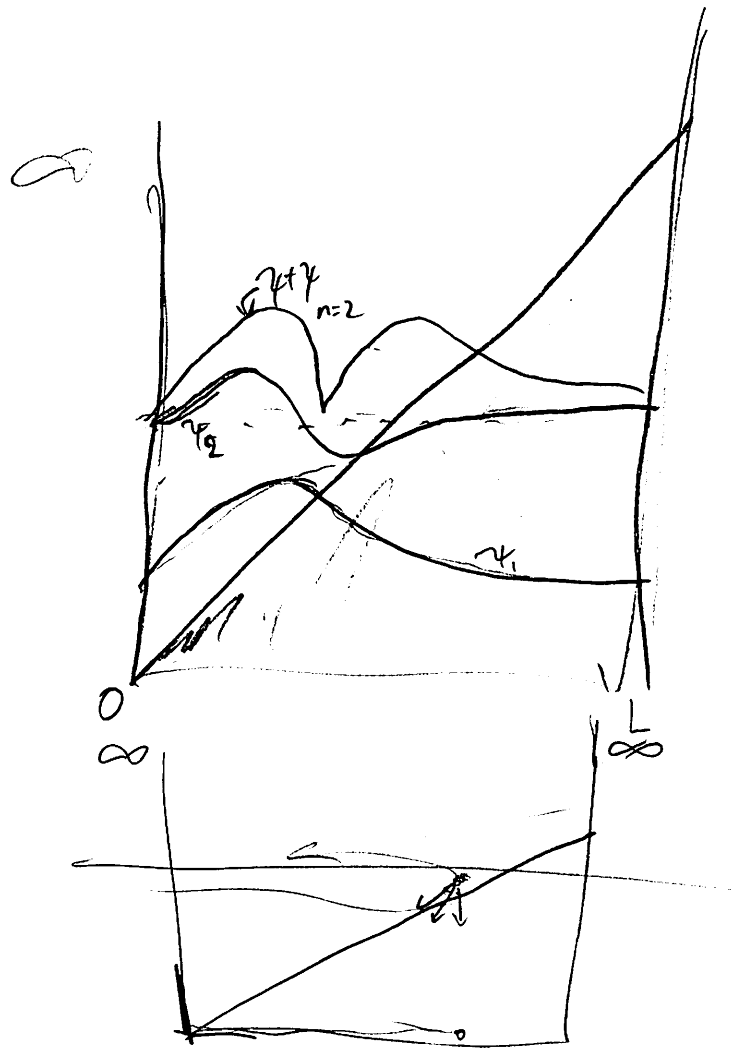
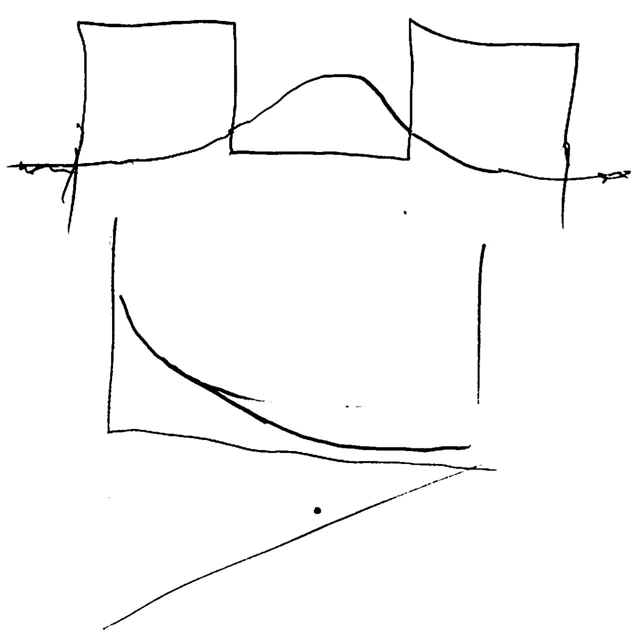
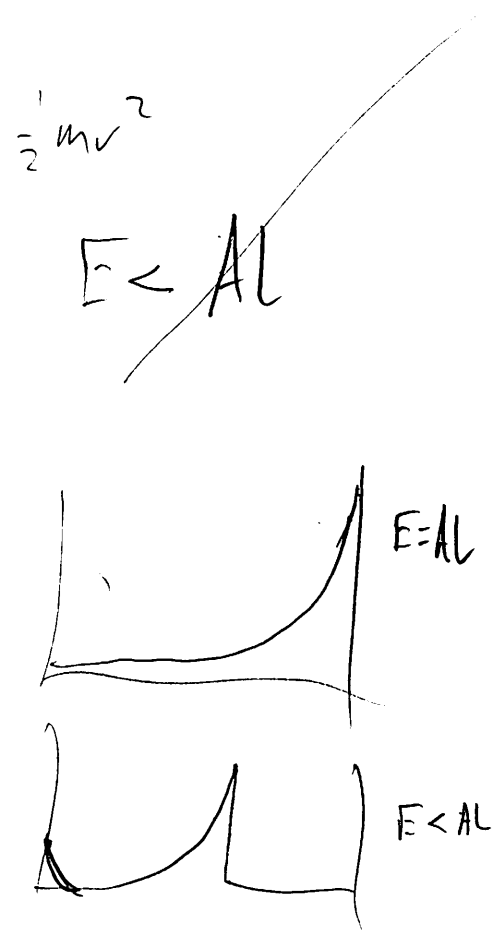
7. Consider a quantum system with V(x) = ∞ for x=(-∞, 0) and (L, ∞), and V(x)= Ax for x=(0, L). Sketch the wavefunction for the first allowed state, or ground state, of the particle.







[1]Chad: Consider a quantum system with V(x)... do do: do do:.. So another particle in a box: ((*begins to draw box of 1*)).... V=Ax oh. Oh. Ok it's particle in a box.
Interviewer: Um: so: I think it's maybe not quite--
Chad: Oh Ax. Sorry I did not quite read that right. You're right. ((*changes bottom of 1 to slant, erases flat bottom*)) Alright, this was one of my final questions.
Interviewer: Was it really?
Chad: Yeah.
Interviewer: No way:.
Chad: Draw the states allowed.
Interviewer: Is this something you guys did in class?
Chad: No. It was only on the final. We talk about how the potential walls affect it ((*traces vertical wall on 1*)). And how it would be uhh... ((*re-traces vertical wall on 1*)) Yeah 'cus we talked, yeah if you talk about, uhh finite regions ((*starts drawing 2*)), you have the wavefunction in here, it doesn't go to zero here ((*starts drawing wavefunction in 2*)), it goes to the points that it does, then exponentially decays in it ((*finishes drawing wavefunction in 2*)).
Interviewer: I see.
Chad: And then... if they're tall enough you get ((*adjusts walls of 2 to go back down to V=0*))... tunneling ((*extends edges of wavefunction in 2*))!
Interviewer: Yay.
Chad: But yeah for this one it would just be, uhh it starts off like it and then it decays ((*draws ground state as he speaks, then higher state in 1)*)).
Interviewer: Okay.
Interviewer: So can you tell me like how you know: like, kinda the shapes of those guys? ((*points to wavefunctions in 1*))
Chad: So it's, you can kind of take it as perturbation upon the particle in the box ((*begins to draw 3*)). So it's going to be essentially particle in the box ((*draws n=1,2 in 3*)) but then, uhh what's happening is as the potential increases ((*draws 4*)), it reduces the probability of being in that region. Which means that if you still normalize it ((*traces n=2 in 3*)), it would have to follow, it would have to follow the same energy, stepping, where it's going by nodes added, but it will reduce the probability of this region ((*circles right hand side of n=2 in 3*)), linearly.
Interviewer: Uhh, this region? Is that... ((*Interviewer points to right side of n=2 in 1*))
Chad: Yeah, this is the ((*shades under slant in 1*))... but, so it will follow essentially it ((*traces part of ground state of PIAB in 1, leaving small line showing where two wavefunctions deviate*)).... I think I made it too big for my waves to look right. But it will go into it generally like that ((*points to n=1 in 3*)). But it will also decay ((*traces remainder of ground state in 1*)) after it enters the region. The probability function, it looks a bit weird on this because it goes past zero ((*draws dotted line in 1 for n=2*)) then comes back out to it slowly.

[1] The transcript uses the following protocols: Elongated words or vowels are marked with a double colon; turns that are cut-off by other speakers or end abruptly are marked with a double hyphen; and actions other than speech, including gestures, are represented in italics and surrounded by double parentheses, (Sacks et al. 1974, Jefferson 2004).