NOTES:

→ Notion of system and state don't really change

But, in quantum mechanics, you can't directly observe the state itself.

- Schrödinger's Eqn. is NOT underdeterministic.

Remember Schrödinger's Equation:

$$i\hbar\frac{\partial\psi}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2\psi + \nabla\psi$$

(linear equation ⇒ leads to entanglement)
(non-relativistic)

"diffusion equation"
$\frac{\partial P}{\partial t} = D\nabla^2 P$

↳ Looks similar mathematically, but they aren't related or smth.

if $\psi(\vec{r},0)$ is known,

one knows $\psi(\vec{r},t)$

(Penrose U process)

- ψ is called the state of the system, generally complex function AND ISN'T DIRECTLY OBSERVABLE.

- An observable operator (differential) acting on ψ.

→ Must have "real" eigenvalues → must have an associated eigenvector.

(hermitian operators)

Only one of those eigenvalues can be measured in one measurement.

What happened after the measurement?
$\longrightarrow$ State changes somehow.

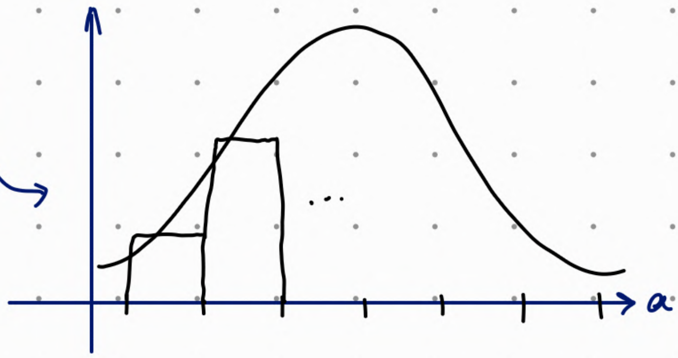
Collapse of The Wave Function (Penrose R process)

The state right after this measurement is the corresponding eigenvector.

(corrolation, Bell experiments)

- The outcome of many repetitions of a measurement will give a distribution of values.

observable is A



$\langle A \rangle$ expectation value.

$\langle A^2 \rangle$ ...

$\langle A^3 \rangle$ ...

$\langle A^n \rangle$ ...

Calculating $\langle A \rangle$:

$$\langle A \rangle_\Psi \equiv \int d^3\vec{r}\, \Psi^*(\vec{r},t)\,(A\,\Psi(\vec{r},t))$$

Time is not an observable! You measure time with motion. We assume it's observable externally.

- Operators you can measure simultaneously:
  - → Simultaneously diagonizable
    - Commuting matrices (Common eigenvalues)

  Complete Set of commuting operators.

- Those who don't commute, are bound on Heisenberg type uncertainty.

If V is not a function of t.

- one can ask for stationary states of definite energy.

$$\Psi(\vec{r},t) = e^{-i\frac{Et}{\hbar}}\, \Psi_E(\vec{r}) \longrightarrow \left(-\frac{\hbar^2}{2m}\nabla^2 + V\right)\Psi_E = E\Psi_E$$

$$\hookrightarrow \Psi(\vec{r},t) = \sum\!\!\!\!\!\!\int_E C_E\, e^{\frac{-iEt}{\hbar}}\, \Psi_E(\vec{r})$$

C_E: expansion coefficients

- Take the norm: $|\Psi_E|^2 = |\Psi(\vec{r})|^2$

Notes:

- Hermitian Operators: • Eigenvectors are orthogonal (linearly independent).
- You can have both discrete and continious eigen values (E in Bohr's model when bound $\rightarrow$ discrete)

Particle in a Box.

(infinite box, Energies are discrete, particle stays in the box.)

$|\Psi(x,t)|^2 = 0$ whenever particle is out $x \leq 0$ and $x \geq L$

$\Psi(x,t) = 0$

for $x \leq 0$ and $x \geq L$.

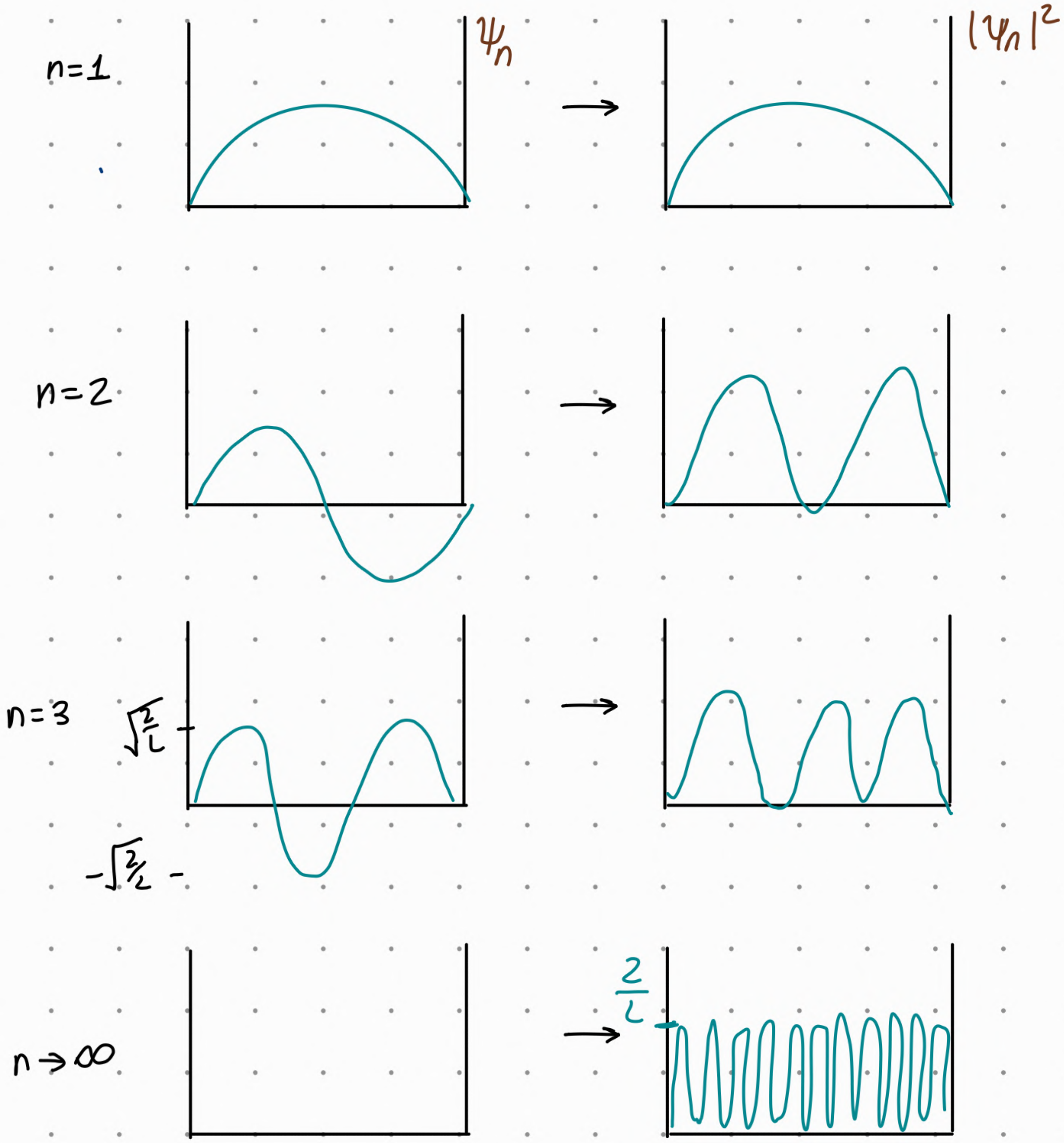
$$\Psi(x=0,t) = \Psi(x=L,t) = 0$$

$$-\frac{\hbar^2}{2m}\frac{d^2\Psi_E(x)}{dx^2} = E\Psi_E(x) \longrightarrow \Psi_n = \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi x}{L}\right)$$

$$E_n = \frac{n^2\pi^2\hbar^2}{2mL^2}$$

$$\Psi(x,t) = \sum_{n=1}^{\infty} C_n\, e^{\frac{-iE_n t}{\hbar}} \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi x}{L}\right)$$

are fixed by $\Psi(x,0)$



It oscillates so much, you expect it to converge to $\Rightarrow$