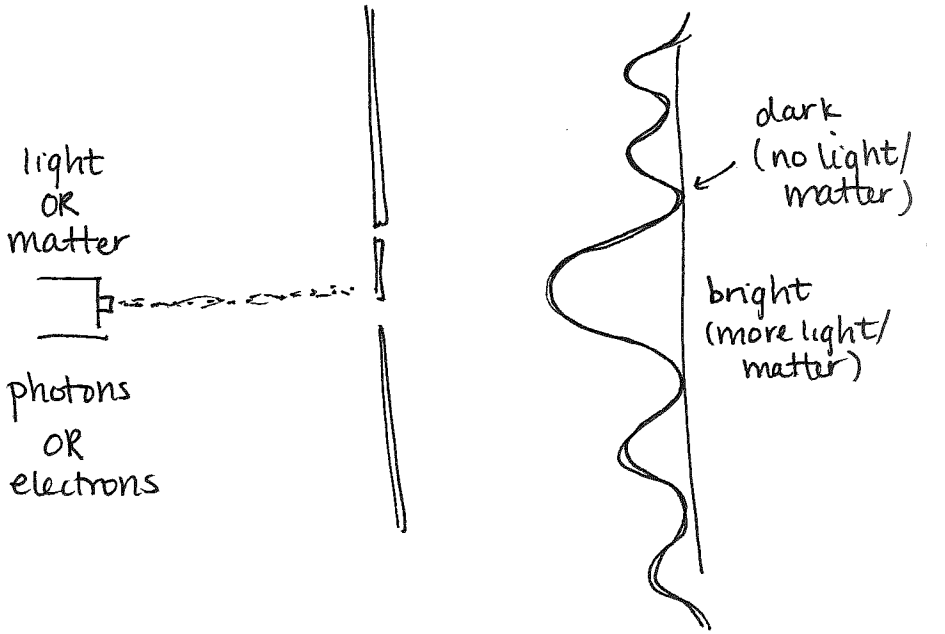
Wavefunctions

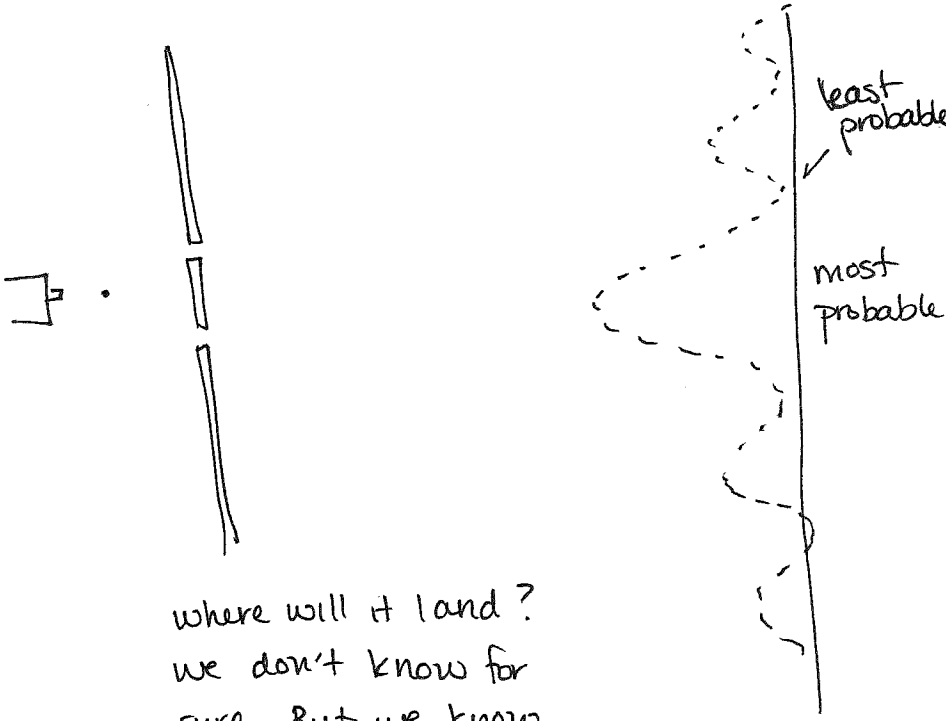
measurement of millions of photons/electrons



can draw a wave that tells us the total results of shooting ~~the~~ millions of photon/electrons at screen

wave = intensity of light/matter
(# photons/electrons that hit a given position)

what if we just shoot one single photon/e⁻?



where will it land?
we don't know for sure. But we know where it is most ~~prob~~ likely & least likely to land

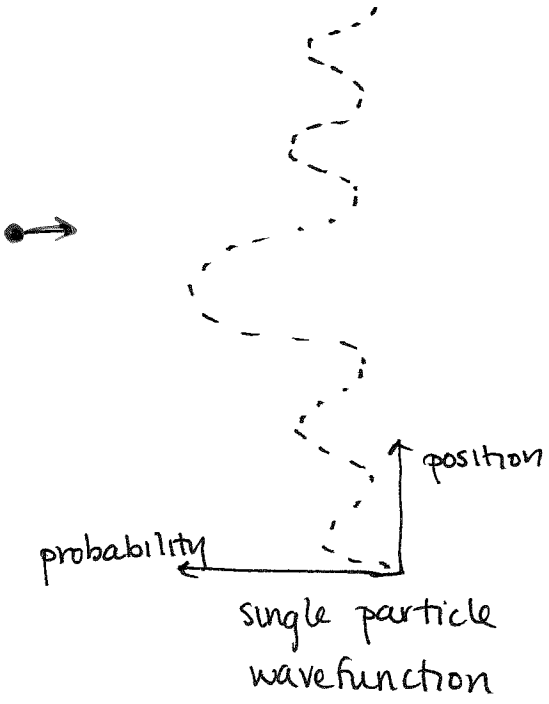
→ know the probability wave

wave = probability of where photon/e⁻ will hit

Single Particle

Probability Wave = Wavefunction

wavefunction of a single particle tells us where the particle is most/least likely to land

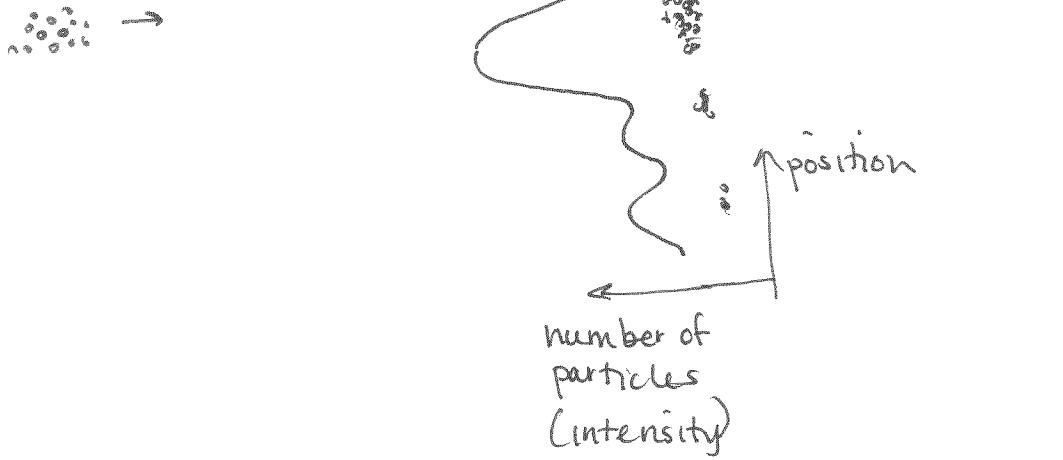


single particle wavefunction

(where is it most likely to land?)

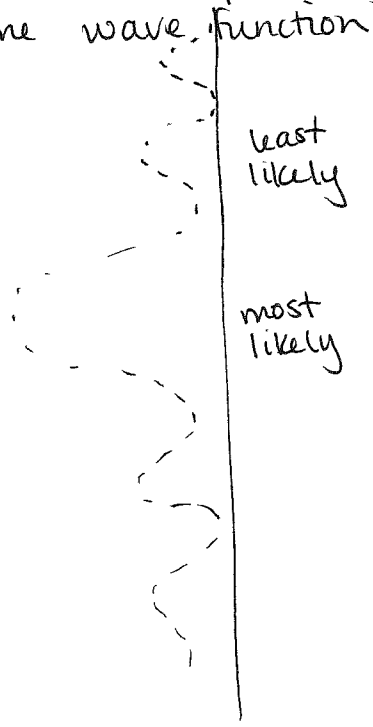
Many Particles

If we send many many particles (each has its own wavefunction), we build up the intensity wave (which has the same shape as the ψ wavefunction:



Wavefunctions

A single particle has a wavefunction that describes where it is most + least likely to land (all particles have same wave function)



single particle

most probable position ⟹ more particles will land at this position ⟹

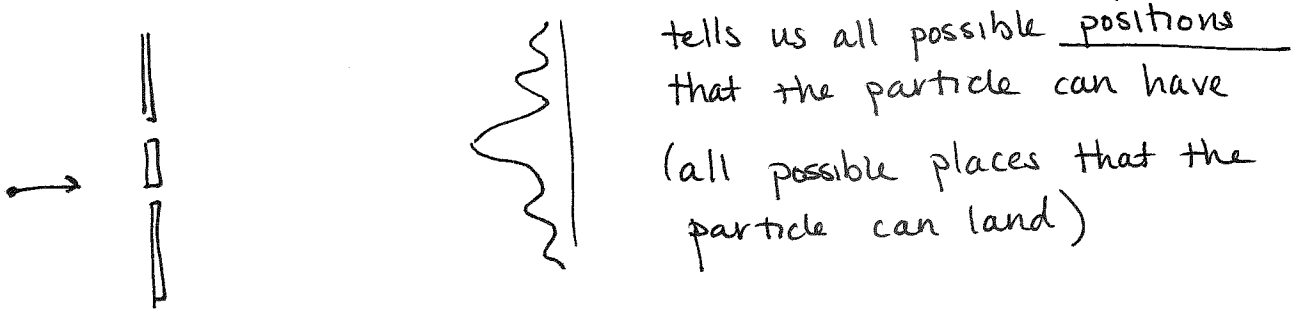
many particles

higher intensity when accumulate many particles

What is the Wavefunction?

wavefunction = probability wave

wavefunction ~~gave~~ tells us all possible states of our system



tells us all possible positions that the particle can have

(all possible places that the particle can land)

wavefunction is superposition of all possible states of our system

→ ~~that does not mean that~~ if we measured particle, we would find it in one state (one of all the possible states)

does tell us: all possible states of ~~system~~ system
how possible each state is

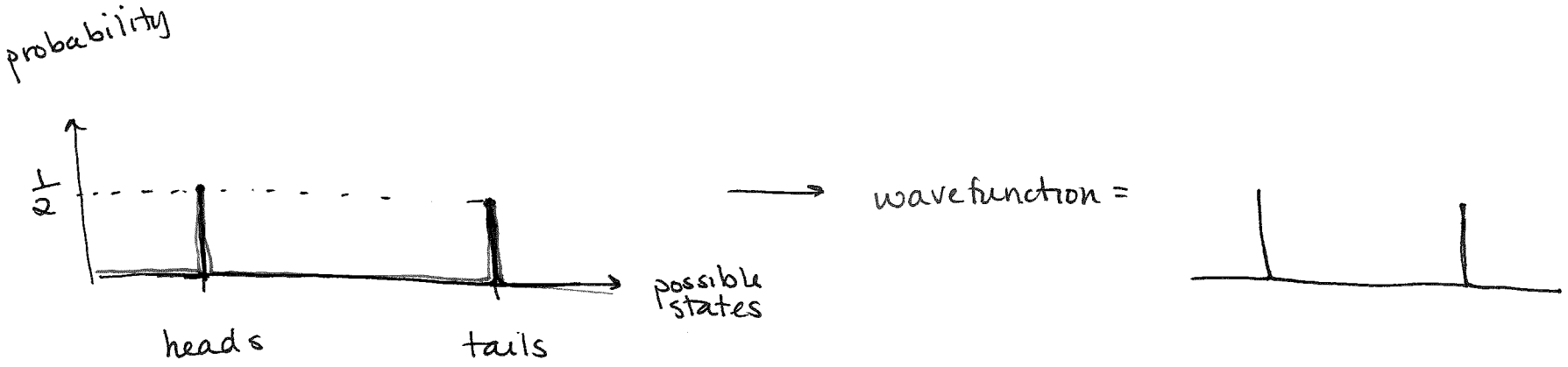
doesn't tell us: exactly which state we will find particle in

Flipping a Coin

consider flipping a coin:

wavefnct tells us prob. of being in each possible state

1. what are possible states?
2. how probable is each state?



$$|\text{coin}\rangle = \sqrt{\tfrac{1}{2}}\,|\text{heads}\rangle + \sqrt{\tfrac{1}{2}}\,|\text{tails}\rangle$$

$\sqrt{\text{probability of heads}}$ $\sqrt{\text{probability of tails}}$

~~coin is in a superposition of heads and tails~~

state of coin is in a superposition of being in state "heads" and state "tails"

$|\text{heads}\rangle$ $|\text{tails}\rangle$

total probability that we will flip either heads or tails?

$$P_{\text{total}} = P_{\text{heads}} + P_{\text{tails}} = \frac{1}{2} + \frac{1}{2} = 1$$

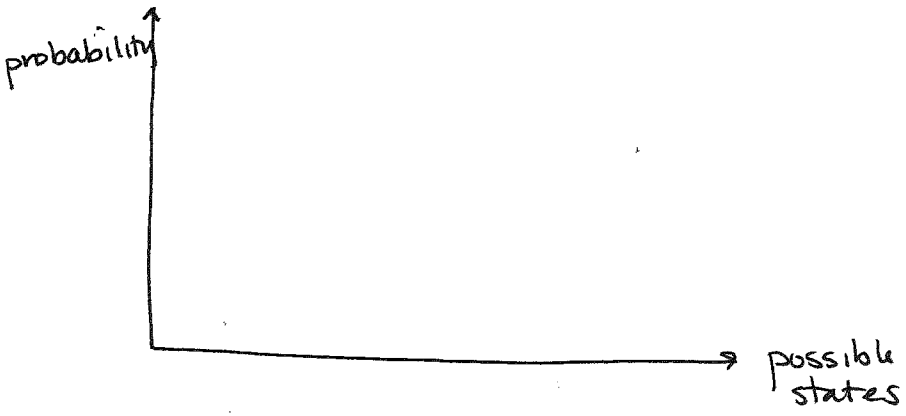
how do we know which it is in?

→ make measurement (we flip the coin)

Try Yourself : 6 sided die

system = die

1. draw wavefunction :



2. write down "state" of die :

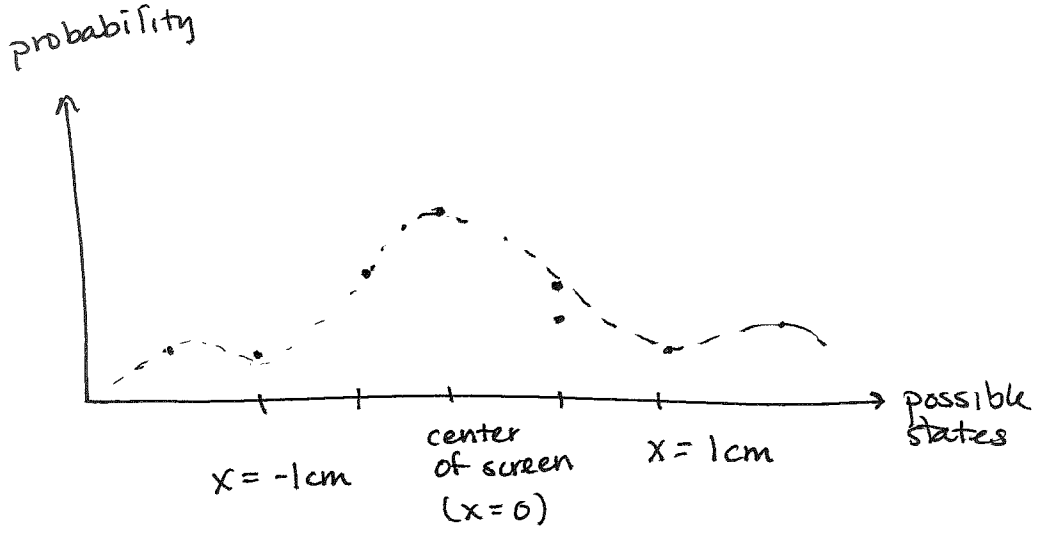
$|die\rangle = ?$

3. Find the total probability

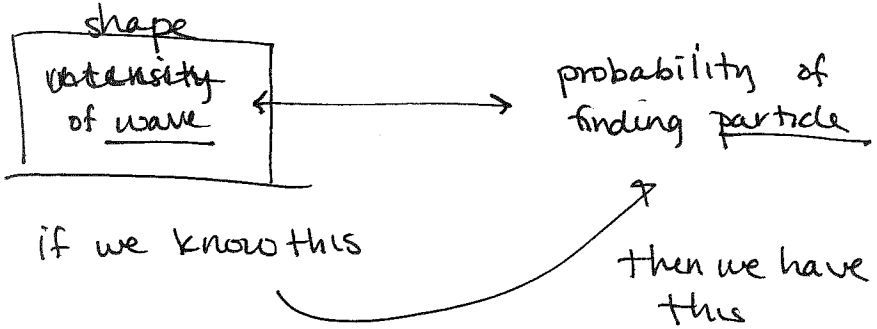
$P_{total} = ?$

do the same thing for any system:

system = particle through double slit

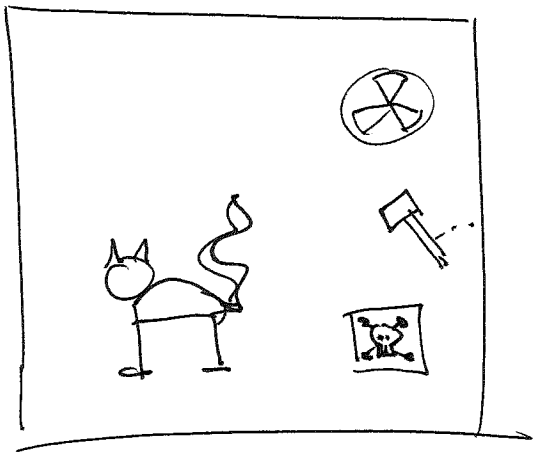


but how do we know all the probabilities?



Schrodinger's Cat Paradox

wavefunction = superposition of all possible states



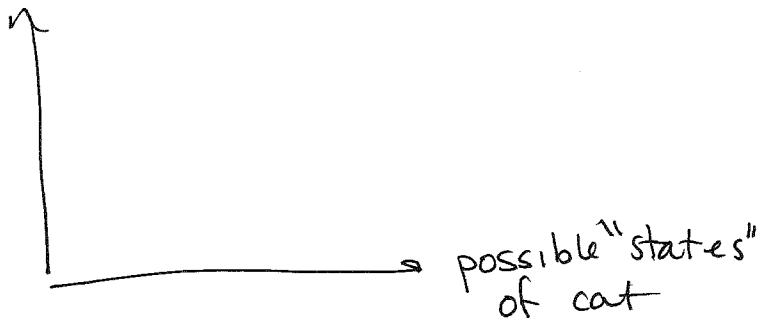
Thought Experiment:

radioactive source:
if atom decays, hammer releases, smashes box, releases poisonous gas, kills cat

After 1 hour:
50% chance that 1 atom has decayed
50% chance that no atom has decayed

1. draw wavefunction → 50% chance that cat is dead
50% chance that cat is alive

probability



2. write down "state" of cat

$|cat\rangle = ?$

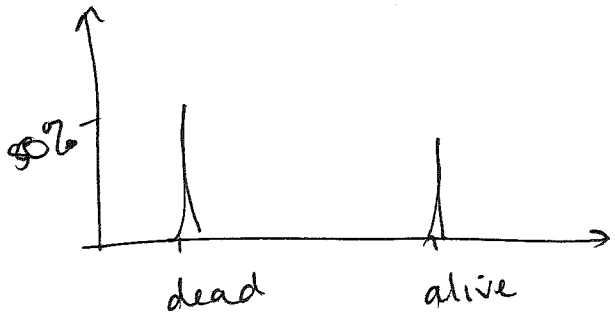
Measurement

How do we find out whether the cat is dead or alive?

→ look in the box = make a measurement

Measurement picks out one of the possible states of our system

before measurement



after measurement