

E. Schrodinger Eqn.  $\leftrightarrow$  Wave mechanics  $\psi$

W. Heisenberg QM  $\leftrightarrow$  Matrix Mechanics

1927 Paul Dirac Unifies both!

Operator Math  
Linear Eqns

$x$  position  $\longrightarrow$   $\psi(x)$   
 $p_x$  momentum  $\psi(p)$   
 $\quad\quad\quad =$

$\bullet$   
 $A$   
 $x(0), p_x(0)$   
 $\underbrace{\hspace{10em}}$   
 $\psi(x, t)$

$EOM$   
 $"t"$

$\bullet$   
 $B$   
 $x(t), p_x(t)$   
 $\underbrace{\hspace{10em}}$

TSE

Hamiltonian

$$H \psi(x, t) = \frac{d}{dt} \psi(x, t) (i\hbar)$$

$\sqrt{-1}$

$$H \psi(x) = E \psi(x)$$

Observation

Dirac.

# Operator Math

(operator) (operand) =

↑  
function

↘

$\frac{d}{dx} f(x)$

→ slope of the

$\int_a^b f(x)$

→ Area  <sup>$f(x)$</sup>  bound by  
a & b limits of  $f(x)$

$\hat{x} \rightarrow \text{position}$   
 $\hat{p}_x \rightarrow \text{momentum}$

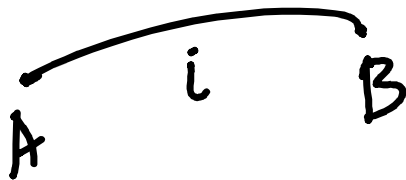
} operator

$$[\hat{x}, \hat{p}_x]$$

$\rightarrow$

$$\hat{x}\hat{p}_x - \hat{p}_x\hat{x} \neq 0$$

function



$\hat{x}$

$$\hat{x} \cdot f \rightarrow x$$

$$\hat{p}_x f \rightarrow p$$

$$\hat{\Omega} \psi = \omega \psi$$

$$\hat{x} \psi \rightarrow \phi$$

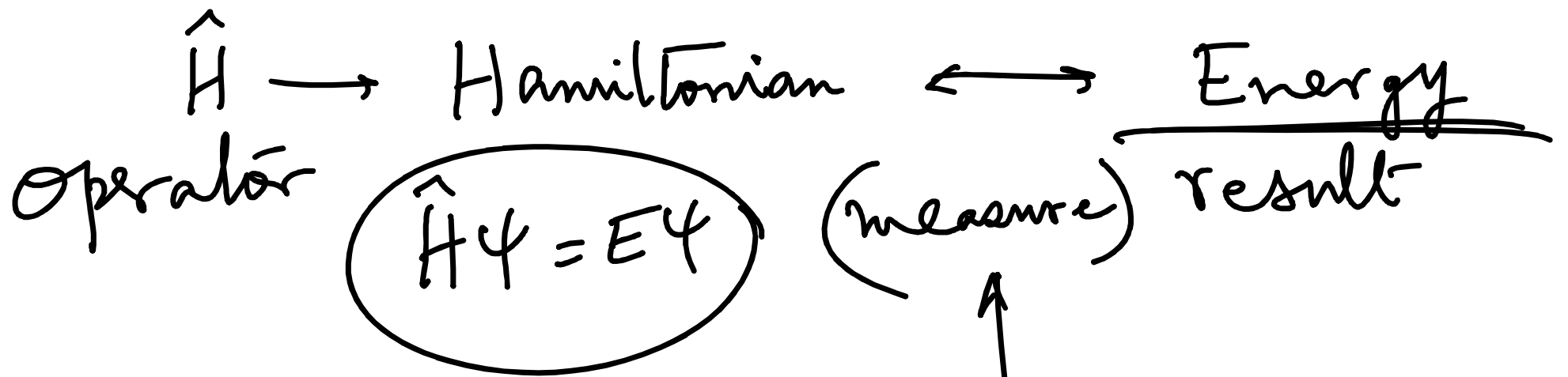
operator

value

Eigen value - function Eqn.

Characteristic Eqns

$$H\psi = E\psi$$



$E \leftrightarrow \hat{H} = \hat{T} + \hat{V}$

$\hat{T}$  KE  
 $\hat{V}$  PE

$\hat{p}_x$  operators  
 $\hat{x}$  operators

$p_x$  position

The diagram shows the equation  $E \leftrightarrow \hat{H} = \hat{T} + \hat{V}$ . Below  $\hat{T}$  is "KE" and below  $\hat{V}$  is "PE". To the right, there are two groups of operators. The first group has  $\hat{p}_x$  above "operators". The second group has  $\hat{x}$  above "operators". An arrow points from the word "position" to the  $\hat{p}_x$  group, and another arrow points from the word "position" to the  $\hat{x}$  group.

$$\hat{H} = \frac{\hat{p}_x^2}{2m} + \hat{V}$$

$$\hat{p}_x = \underbrace{\pm i\hbar}_{\uparrow} \frac{d}{dx}$$

$$\hat{p}_x^2 \rightarrow \hat{p}_x \cdot \hat{p}_x$$

$$-\hbar^2 \frac{d^2}{dx^2}$$

$$-i\hbar \frac{d}{dx}$$

$$\frac{1-D}{\hbar}$$

$$V=0$$