# Advanced Quantum Mechanics

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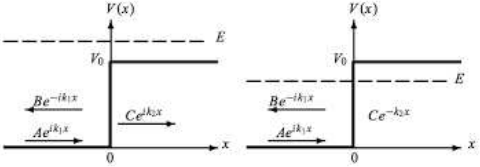
# Quantum Step Problem

- $E < V_0$

The potential functions are : $V(x) = 0$ when $x < 0$ and $V(x) = V_0$ when $x \geq 0$ Lets write down the general formula of Schrodinger equation again:

$$-\frac{\hbar^2}{2m}\frac{d^2\Psi(x)}{dx^2} + V(x)\Psi(x) = E\Psi(x)$$



$V(x)$
$E$
$V_0$
$Be^{-ik_1x}$
$Ce^{ik_2x}$
$Ae^{ik_1x}$
$x$
0
$V(x)$
$V_0$
$E$
$Be^{-ik_1x}$
$Ce^{-k_2x}$
$Ae^{ik_1x}$
$x$
0

As we divided space into two regions lets write Schrodinger equation for every region:

$$-\frac{\hbar^2}{2m}\frac{d^2\Psi_I(x)}{dx^2} = E\Psi_I(x), \quad In \quad region \quad I: \quad x<0$$

$$-\frac{\hbar^2}{2m}\frac{d^2\Psi_{II}(x)}{dx^2} + V_0\Psi(x) = E\Psi_{II}(x), \quad In \quad region \quad II: \quad x \geq 0$$

Following these relation we found that our wave-functions are:

$$\Psi_I = Ae^{ik_I x} + Be^{-ik_I x}, \quad k_I = \frac{\sqrt{2mE}}{\hbar}$$

$$\Psi_{II} = Ce^{k_{II} x} + De^{-k_{II} x}, \quad k_{II} = \frac{\sqrt{2m(V_0 - E)}}{\hbar}, \quad \boxed{C = 0}$$

The current density: $J = \frac{i\hbar}{2m}(\Psi(x)\frac{d\Psi^*}{dx} - \Psi^*(x)\frac{d\Psi}{dx})$ . Then the transmission and reflection probability is $R = \frac{|J_{ref}|}{|J_{in}|}$ and $T = \frac{|J_{tra}|}{|J_{in}|}$.

$$R = \frac{|J_{ref}|}{|J_{in}|} = \frac{|B|^2}{|A|^2}$$

$$T = \frac{|J_{tra}|}{|J_{in}|} = 0$$

$$R + T = 1$$

The continuity condition requires that:

$$\Psi_I(0) = \Psi_{II}(0), \quad \textit{boundary} \quad \textit{between} \quad \textit{regionsI} \quad \textit{and} \quad \textit{II}$$

Also, the first derivatives of the solution must e continuous at region boundaries:

$$[x = 0] \quad \rightarrow \quad \frac{d\Psi_I(x)}{dx} = \frac{d\Psi_{II}(x)}{dx}$$

then we can write:

$$A + B = D \quad and \quad ik_I(A - B) = -ik_{II}D$$

from those relations $B = \frac{k_I - ik_2}{k_I + ik_{II}}A$ and $D = \frac{2k_I}{k_I + k_2}A$ from this:

$$R = \frac{|k_I - ik_{II}|^2}{|k_I + ik_2|^2} = 1$$