Universidade Federal do ABC

Disciplina - BC1419

Título

Docente: Professor

Autor A	RA: 00000000
Autor B	RA: 11111111
Autor C	RA: 22222222
Autor D	RA: 33333333

Santo André

Data

Sumário

Resumo

1 Introdução

1.1 Transformada normalizada de Fourier

$$\langle x|p\rangle = \frac{1}{\sqrt{2\pi\hbar}} e^{i\frac{p}{\hbar}x} \tag{1.1}$$

$$\langle p|x\rangle = \frac{1}{\sqrt{2\pi\hbar}} e^{-i\frac{p}{\hbar}x} \tag{1.2}$$

$$|\psi\rangle = \int \psi(x)\,|x\rangle\,\mathrm{d}x = \int \hat{\psi}(p)\,|p\rangle\,\mathrm{d}p \tag{1.3}$$

$$\psi(x) = \langle x|\psi\rangle = \frac{1}{\sqrt{2\pi\hbar}} \int \hat{\psi}(p) e^{i\frac{p}{\hbar}x}\,\mathrm{d}p \tag{1.4}$$

$$\hat{\psi}(p) = \langle p|\psi\rangle = \frac{1}{\sqrt{2\pi\hbar}} \int \psi(x) e^{-i\frac{p}{\hbar}x}\,\mathrm{d}x \tag{1.5}$$

1.2 Propriedades

1.2.1 Transformada da derivada com relação a x

Seja

$$D_x\,|\psi\rangle = \left|\frac{\mathrm{d}\psi}{\mathrm{d}x}\right\rangle = \int \frac{\mathrm{d}\psi}{\mathrm{d}x}\,|x\rangle\,\mathrm{d}x \tag{1.6}$$

então

$$\langle p|D_x|\psi\rangle = \frac{1}{\sqrt{2\pi\hbar}} \int \frac{\mathrm{d}\psi}{\mathrm{d}x} e^{-i\frac{p}{\hbar}x}\,\mathrm{d}x \tag{1.7}$$

$$\langle p|D_x|\psi\rangle = \frac{1}{\sqrt{2\pi\hbar}}\,\psi(x)e^{-i\frac{p}{\hbar}x}\Big|_{-\infty}^{+\infty} + \frac{ip}{\hbar}\frac{1}{\sqrt{2\pi\hbar}} \int \psi(x) e^{-i\frac{p}{\hbar}x}\,\mathrm{d}x \tag{1.8}$$

$$\langle p|D_x|\psi\rangle = \frac{ip}{\hbar}\hat{\psi}(p) = \frac{i}{\hbar}\,\langle p|p\psi\rangle \tag{1.9}$$

1.2.2 Transformada inversa da derivada com relação a p

Seja

$$D_p \left|\psi\right\rangle = \left|\frac{\mathrm{d}\psi}{\mathrm{d}p}\right\rangle = \int \frac{\mathrm{d}\hat{\psi}}{\mathrm{d}p} \left|p\right\rangle \mathrm{d}p \tag{1.10}$$

então

$$\langle x|D_p|\psi\rangle = \frac{1}{\sqrt{2\pi\hbar}} \int \frac{\mathrm{d}\hat{\psi}}{\mathrm{d}p} e^{i\frac{p}{\hbar}x}\,\mathrm{d}p \tag{1.11}$$

$$\langle x|D_p|\psi\rangle = \frac{1}{\sqrt{2\pi\hbar}}\, \hat{\psi}(p) e^{i\frac{p}{\hbar}x}\Big|_{-\infty}^{+\infty} - \frac{ix}{\hbar}\frac{1}{\sqrt{2\pi\hbar}} \int \hat{\psi}(p) e^{i\frac{p}{\hbar}x}\,\mathrm{d}p \tag{1.12}$$

$$\langle x|D_p|\psi\rangle = \frac{-ix}{\hbar}\psi(x) = \frac{-i}{\hbar} \left\langle x|x\psi\right\rangle \tag{1.13}$$

2 Transformada de funções

2.1 Constante

$$|f\rangle = \int A\,|x\rangle\,\mathrm{d}x \tag{2.1}$$

$$\langle p|f\rangle = \frac{1}{\sqrt{2\pi\hbar}}\int Ae^{-i\frac{p}{\hbar}x}\,\mathrm{d}x = A\sqrt{2\pi\hbar}\delta(p) \tag{2.2}$$

Onde foi usado que

$$\frac{1}{2\pi}\int_{-\infty}^{+\infty} e^{ikx}\,\mathrm{d}x = \delta(k) \tag{2.3}$$

2.2 Delta de Dirac

$$|\delta\rangle = \int \delta(x)\,|x\rangle\,\mathrm{d}x \tag{2.4}$$

$$\langle p|\delta\rangle = \frac{1}{\sqrt{2\pi\hbar}}\int \delta(x)e^{-i\frac{p}{\hbar}x}\,\mathrm{d}x = \frac{1}{\sqrt{2\pi\hbar}} \tag{2.5}$$

2.3 Degrau de Heaviside

$$|\Theta\rangle = \int \Theta(x)\,|x\rangle\,\mathrm{d}x \tag{2.6}$$

$$\langle p|\Theta\rangle = \frac{1}{\sqrt{2\pi\hbar}}\int \Theta(x)e^{-i\frac{p}{\hbar}x}\,\mathrm{d}x = \tag{2.7}$$

2.4 Função retangular

2.5 Função triangular

2.6 Função sinc

2.7 Função sinal

2.8 Pente de Dirac

2.9 Potência

$$|x^n\rangle = \int x^n \, |x\rangle \, \mathrm{d}x \tag{2.8}$$

$$\langle p|x^n\rangle = \frac{1}{\sqrt{2\pi\hbar}} \int x^n e^{-i\frac{p}{\hbar}x} \, \mathrm{d}x = (i\hbar)^n \frac{\partial^n}{\partial p^n} \frac{1}{\sqrt{2\pi\hbar}} \int e^{-i\frac{p}{\hbar}x} \, \mathrm{d}x \tag{2.9}$$

$$\langle p|x^n\rangle = \sqrt{2\pi\hbar}(i\hbar)^n \delta^{(n)}(p) = \sqrt{2\pi\hbar^{2n+1}} i^n \delta^{(n)}(p) \tag{2.10}$$

2.10 Potência negativa

2.11 Exponencial

2.12 Seno

2.13 Cosseno

2.14 Gaussiana

Seja a gaussiana

$$|g\rangle = \frac{1}{\sqrt{2\pi\sigma^2}} \int e^{-\frac{(x-\mu)^2}{2\sigma^2}} \, |x\rangle \, \mathrm{d}x \tag{2.11}$$

então

$$D_x \left|g\right\rangle = \frac{1}{\sqrt{2\pi\sigma^2}} \int -\frac{x-\mu}{\sigma^2} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \left|x\right\rangle \mathrm{d}x \tag{2.12}$$

$$D_x \left|g\right\rangle = \frac{1}{\sqrt{2\pi\sigma^2}} \int -\frac{x}{\sigma^2} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \left|x\right\rangle \mathrm{d}x + \frac{1}{\sqrt{2\pi\sigma^2}} \int \frac{\mu}{\sigma^2} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \left|x\right\rangle \mathrm{d}x \tag{2.13}$$

$$D_x \left|g\right\rangle = -\frac{1}{\sigma^2} \left|xg\right\rangle + \frac{\mu}{\sigma^2} \left|g\right\rangle \tag{2.14}$$

$$\frac{i}{\hbar} \left|pg\right\rangle = -\frac{i\hbar}{\sigma^2} D_p \left|g\right\rangle + \frac{\mu}{\sigma^2} \left|g\right\rangle \tag{2.15}$$

$$D_p \left|g\right\rangle = -\frac{\sigma^2}{\hbar^2} \left|pg\right\rangle - \frac{i\mu}{\hbar} \left|g\right\rangle \tag{2.16}$$

$$\left\langle p\right| D_p \left|g\right\rangle = -\frac{\sigma^2}{\hbar^2} \left\langle p|pg\right\rangle - \frac{i\mu}{\hbar} \left\langle p|g\right\rangle \tag{2.17}$$

$$\frac{\mathrm{d}\hat{g}}{\mathrm{d}p} = -\frac{\sigma^2 p}{\hbar^2} \hat{g} - \frac{i\mu}{\hbar} \hat{g} \tag{2.18}$$

$$\int_{\hat{g}(0)}^{\hat{g}(p)} \frac{1}{\hat{g}} \,\mathrm{d}\hat{g} = \int_0^p -\frac{\sigma^2 p}{\hbar^2} - \frac{i\mu}{\hbar} \,\mathrm{d}p \tag{2.19}$$

$$\ln \hat{g}(p) = -\frac{\sigma^2 p^2}{2\hbar^2} - \frac{i\mu p}{\hbar} \tag{2.20}$$

$$\hat{g}(p) = e^{-\frac{\sigma^2 p^2}{2\hbar^2} - \frac{i\mu p}{\hbar}} \tag{2.21}$$

2.15 Secante hiperbólica

3 Metodologia

3.1 Lista de materiais

- primeiro

3.2 Montagem experimental

3.3 Procedimento experimental

4 Resultados e análise de dados

5 Conclusão

Referências

A Demonstrações

B Propagação de incertezas

i	a	b
1	A	B
2	C	D

Tabela 1 – Exemplo de tabela.

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Figura 1 – Exemplo de imagem.