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Fourier integral

* Fourier integral can be represented as;

$$\rightarrow f(x) = \int_0^{\infty} [A(\omega) \cos \omega x + B(\omega) \sin \omega x] \, d\omega .$$

$$- A(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} f(v) \cos \omega v \cdot dv.$$

$$- B(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} f(v) \sin \omega v \cdot dv.$$

* Fourier cosine integral.

$$A(\omega) = \frac{2}{\pi} \int_0^{\infty} f(v) \cos \omega v \, dv.$$

* Fourier sine integral.

$$B(\omega) = \frac{2}{\pi} \int_0^{\infty} f(v) \sin \omega v \, dv.$$

* find the fourier integral representation of function :-

$$f(x) = \begin{cases} 1 & \text{if } |x| < 1 \\ 0 & \text{if } |x| > 1. \end{cases}$$

Hence, evalute (i). $\int_0^\infty \frac{\sin\omega \cdot \cos\omega x}{\omega} \, d\omega.$

(ii) . $\int_0^\infty \frac{\sin\omega}{\omega} \, d\omega.$

$\Rightarrow$ $f(-x) = \begin{cases} 1 & \text{if } |-x| < 1 \\ 0 & \text{if } |-x| > 1. \end{cases}$

Here, function is even.

$$A(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} f(v) \cos\omega v \, dv.$$

$$= \frac{2}{\pi} \int_0^\infty f(v) \cos\omega v \, dv.$$

$$= \frac{2}{\pi} \int_0^1 1 \cdot \cos\omega v \, dv + \int_1^\infty 0 \cdot \cos\omega v \, dv.$$

$$= \frac{2}{\pi} \left[\frac{\sin\omega v}{\omega} \right]_0^1$$

$$= \frac{2}{\pi} \left[\frac{\sin\omega}{\omega} - 0 \right] = \frac{2}{\pi} \cdot \left[\frac{\sin\omega}{\omega} \right]$$

$\rightarrow f(x) = \int_0^\infty A(\omega) \cos\omega x \cdot d\omega.$

$= \int_0^\infty \frac{2}{\pi} \cdot \frac{\sin\omega}{\omega} \cos\omega x \; d\omega.$

$= \frac{2}{\pi} \int_0^\infty \frac{\sin\omega}{\omega} \cdot \cos\omega x \; d\omega.$

(i) $\rightarrow \frac{\pi}{2} f(x) = \int_0^\infty \frac{\sin\omega}{\omega} \cdot \cos\omega x \; d\omega.$

$= \begin{cases} \pi/2 & \text{if } |x| < 1. \\ 0 & \text{if } |x| > 1. \end{cases}$

(ii) $\rightarrow \frac{\pi}{2} f(0) = \int_0^\infty \frac{\sin\omega}{\omega} \cdot \cos\omega(0) \; d\omega.$

$= \int_0^\infty \frac{\sin\omega}{\omega} \; d\omega.$

$\pi/4$

$\pi/2$

$\frac{2}{\pi} \cdot \frac{\pi}{8}$

$f(0) = \frac{1}{2} \left[\lim_{x \to 1^+} f(x) + \lim_{x \to 1^-} f(x) \right]$

$= \frac{1}{2} \left[0 + \pi/2 \right]$

$= \pi/4$

* Using fourier integral representation prove that,

$$\int_0^\infty \frac{\cos\omega x + \omega \sin \omega x}{1+\omega^2}\, d\omega.$$

$$= \begin{cases} 0 & \text{if} \quad x < 0 \\ \pi/2 & \text{if} \quad x = 0 \\ \pi \cdot e^{-x} & \text{if} \quad x > 0. \end{cases}$$

→ $f(x) = \int_0^\infty [A(\omega) \cos \omega x + B(\omega) \sin \omega x]\, d\omega$.

– $A(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} f(v) \cos \omega v \, d\cancel{v}$

$$= \frac{1}{\pi} \int_{-\infty}^{0} 0 \cdot \cos \omega v \, dv + \int_0^\infty \pi \cdot e^{-\cancel{x}} \cdot \cos \omega v \, dv.$$

$$= \frac{\cancel{\pi}}{\cancel{\pi}} \int_0^\infty e^{-v} \cdot \cos \omega v \, dv.$$

$e^{ax} \cdot \cos b\cancel{x}. \quad a = -1, \; b = \omega.$

$$= \left\{ \frac{e^{-v}}{1+\omega^2} \left[-\cos \omega v + \omega \sin \omega v \right] \right\}_0^\infty.$$

$$= 0 - \frac{1}{1+\omega^2} (-1)$$

$$= \frac{1}{1+\omega^2}.$$

- $B(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} f(v) \sin \omega v \; dv.$

$$= \frac{1}{\pi} \int_{-\infty}^{0} 0 \cdot \sin \omega v \; dv + \int_{0}^{\infty} \pi \cdot e^{\cancel{v}} \cdot \sin \omega v \; dv.$$

$$= \frac{\pi}{\pi} \int_{0}^{\infty} e^{-v} \cdot \sin \omega v \; dv.$$

$a = -1 \qquad b = \omega.$

$$= \left[\frac{e^{-v}}{1 + \omega^2} \left\{ -\sin \omega v - \omega \cos \omega v \right\} \right]_{0}^{\infty}.$$

$$= 0 - \frac{1}{1+\omega^2} \cdot - \omega (1)$$

$$= \frac{\omega}{1+\omega^2}.$$

- $f(x) = \int_{0}^{\infty} \left[A(\omega) \cos \omega x + B(\omega) \sin \omega x \right] d\omega.$

$$= \int_{0}^{\infty} \left(\frac{1}{1+\omega^2} \cos \omega x + \frac{\omega}{1+\omega^2} \cdot \sin \omega x \right) d\omega.$$

$$\therefore f(x) = \int_{0}^{\infty} \frac{\cos \omega x + \omega \sin \omega x}{1 + \omega^2} \; d\omega.$$

$$= \begin{cases} 0 & \text{if} \quad x < 0 \\ \pi/2 & \text{"} \quad x = 0 \\ \pi \cdot e^{-x} & \text{"} \quad x > 0. \end{cases}$$

cosine integral.

* $f(x) = e^{-kx}$. where, $k > 0$, $x > 0$.

$A(\omega) = \frac{2}{\pi} \int_0^\infty f(v) \cos \omega v \, dv$.

$= \frac{2}{\pi} \int_0^\infty e^{-kv} \cdot \cos \omega v \, dv$.

$a = -k$. $b = \omega$.

$= \frac{2}{\pi} \left[\frac{e^{-kv}}{k^2 + \omega^2} \left\{ -k \cos \omega v + \omega \sin \omega v \right\} \right]_0^\infty$.

$= \frac{2}{\pi} \left[0 - \frac{1}{k^2 + \omega^2} \left\{ -k(1) + 0 \right\} \right]$.

$= \frac{2}{\pi} \left[\frac{-1}{k^2 + \omega^2} \cdot -k \right]$.

$= \frac{2}{\pi} \cdot \frac{k}{k^2 + \omega^2}$.

$\rightarrow f(x) = \int_0^\infty \frac{2}{\pi} \cdot \frac{k}{k^2 + \omega^2} \cdot \cos \omega x \, d\omega$.

$= \frac{2}{\pi} \int_0^\infty \frac{k}{k^2 + \omega^2} \cdot \cos \omega x \, d\omega$.