

Taylor Series

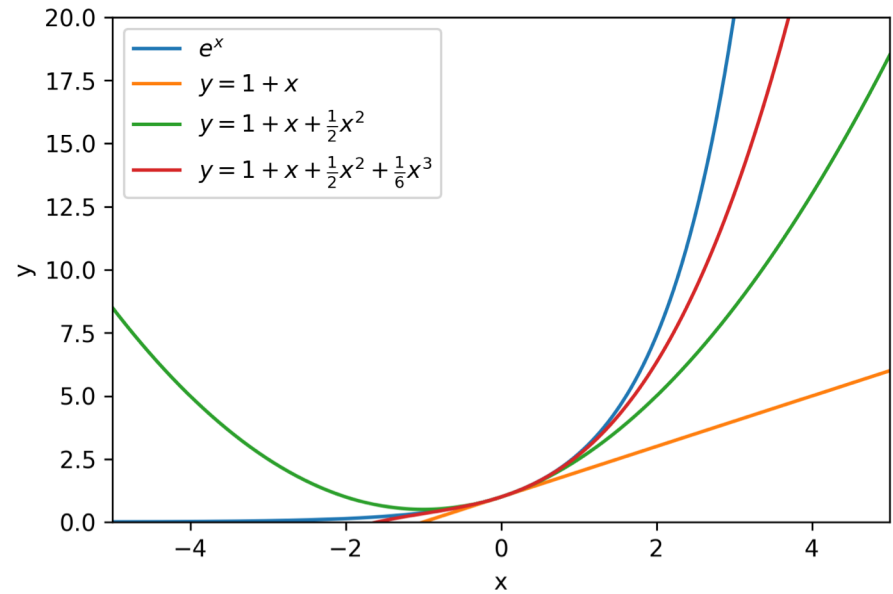
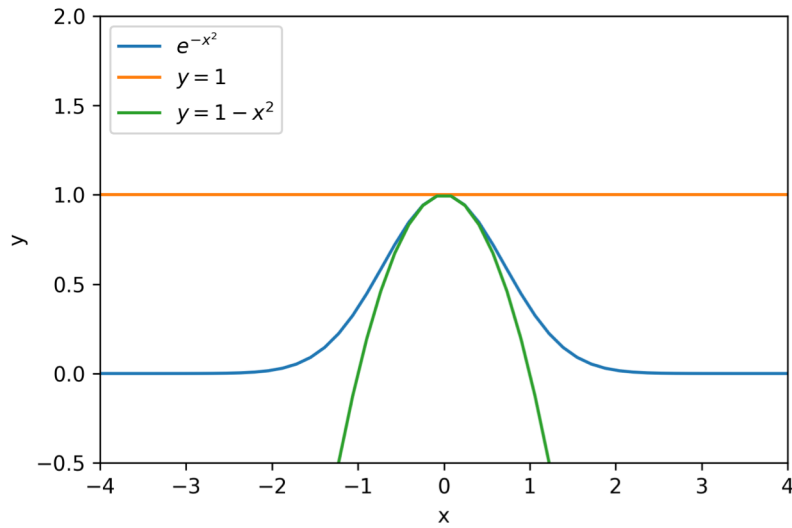
창원대학교 신소재공학부

정영웅

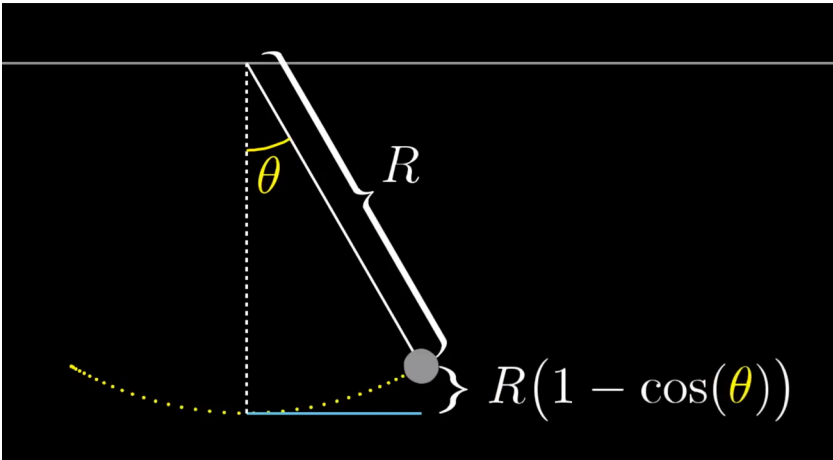


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<https://youngung.github.io>
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Taylor series (테일러 급수)



회전추의 높이



$$\cos(\theta) \approx 1 - \frac{\theta^2}{2}$$

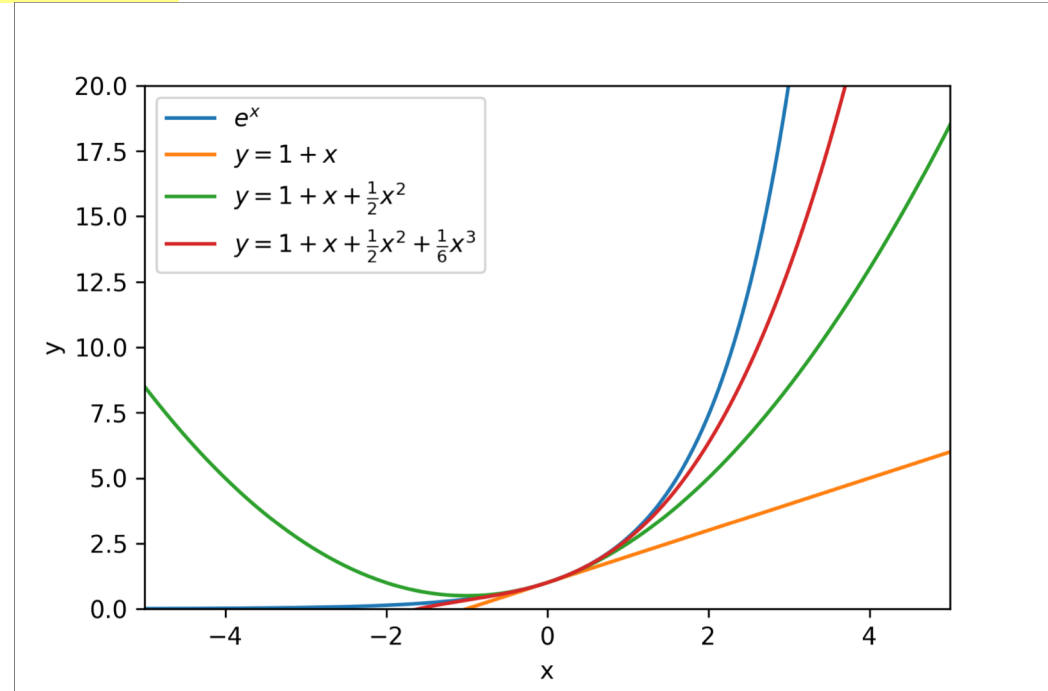
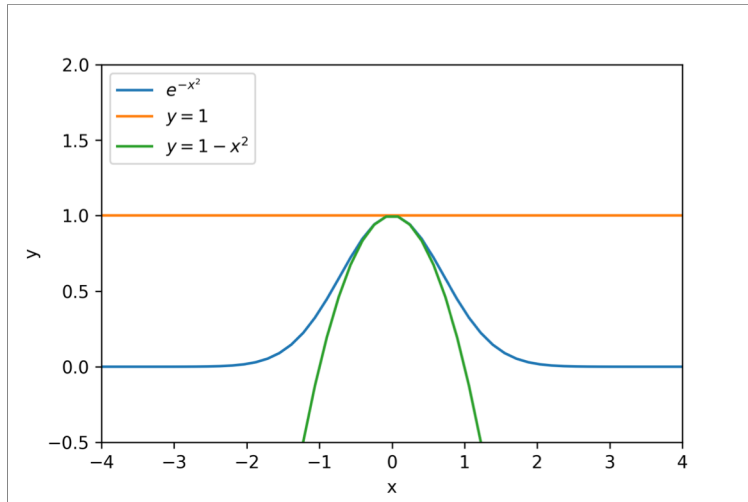
<https://youtu.be/3d6DsjlBzJ4?t=38>



Polynomial (다항식)

□ Taylor series **approximate** an arbitrary function in the form of a polynomial

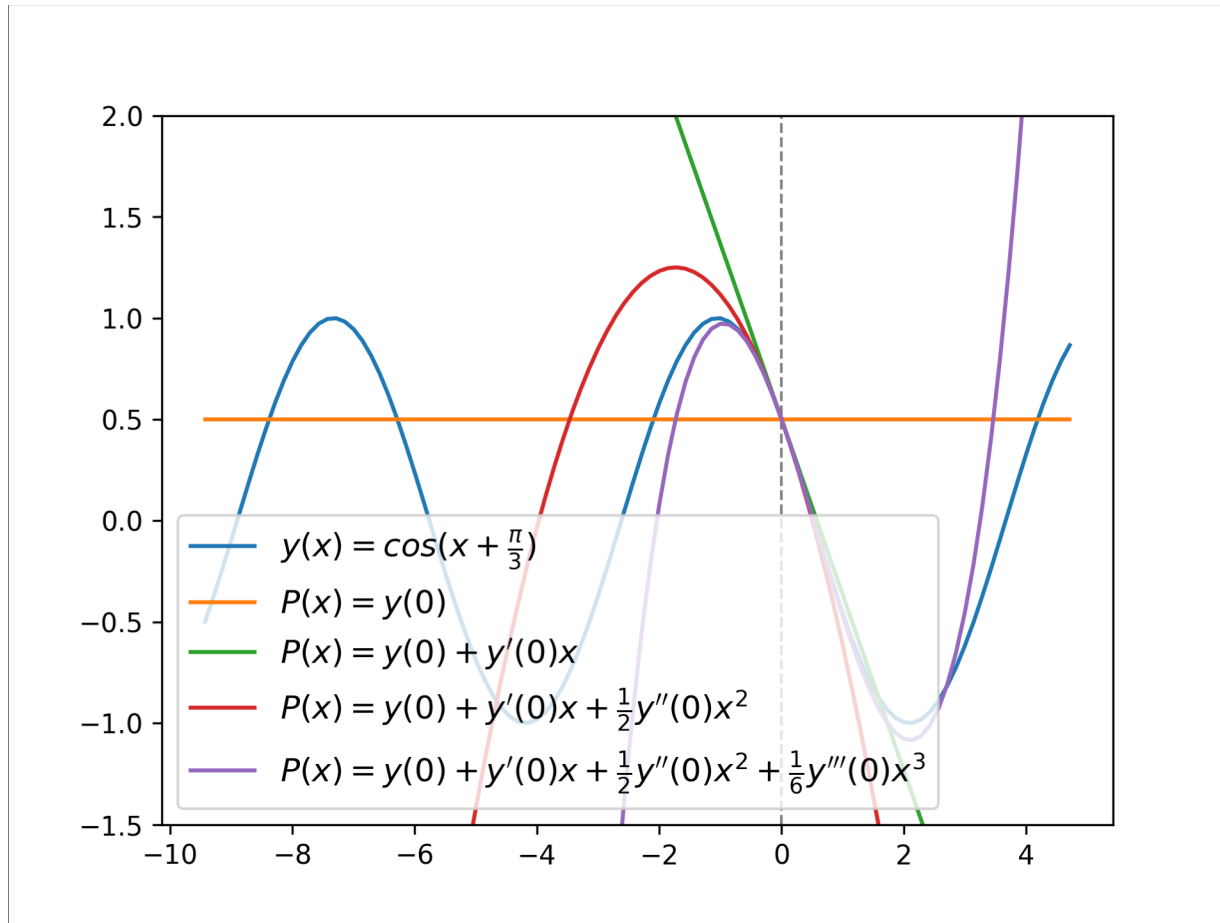
$$y(x) = a + bx + cx^2 + dx^3 \dots \text{and on on}$$



How to?

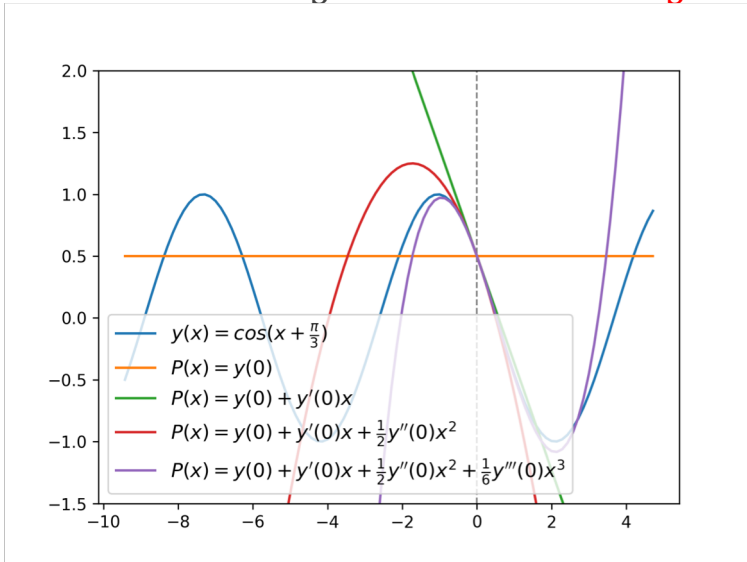
Example of $y = \cos\left(x + \frac{\pi}{3}\right)$

$P(x) = a + bx + cx^2 \dots$



Verification

$$y(x) = \cos\left(x + \frac{\pi}{3}\right) \approx P(x) = \cos\left(0 + \frac{\pi}{3}\right) - \sin\left(0 + \frac{\pi}{3}\right)x - \frac{1}{2}\cos\left(0 + \frac{\pi}{3}\right)x^2 + \frac{1}{6}\sin\left(0 + \frac{\pi}{3}\right)x^3$$



$$y(0.1) = \cos\left(0.1 + \frac{\pi}{3}\right) = 0.41104380 \dots$$

$$\cos\left(\frac{\pi}{3}\right) = 0.500000$$

$$\cos\left(\frac{\pi}{3}\right) - \sin\left(\frac{\pi}{3}\right) \times 0.1 = 0.413397 \dots$$

$$\cos\left(\frac{\pi}{3}\right) - \sin\left(\frac{\pi}{3}\right) \times 0.1 - \frac{1}{2}\cos\left(\frac{\pi}{3}\right) \times 0.01 = 0.410897 \dots$$

$$\cos\left(\frac{\pi}{3}\right) - \sin\left(\frac{\pi}{3}\right) \times 0.1 - \frac{1}{2}\cos\left(\frac{\pi}{3}\right) \times 0.01 + \frac{1}{6}\sin\left(\frac{\pi}{3}\right) \times 0.001 = 0.411041 \dots$$



Generalization

$$y = f(x)$$

Taylor series of $f(x)$ at $x = a$?

$$= f(x = a) + \frac{df}{dx}(x = a) \times (x - a) + \frac{1}{2} \frac{d^2f}{dx^2}(x = a) \times (x - a)^2$$

$$\frac{df}{dx}(x = a)$$

도함수 $\frac{df}{dx}$ 가 x 의 함수라면, x 에 a 를
대입하여라.

통상, 2차항까지만 해도 제법 훌륭한
approximation 가능.



Numerical solution of ODE using Taylor series

$$\frac{dy(t)}{dt} = f(t, y)$$

Let's say we have a initial state such that
 $y(t = 0) = y_0$

$$\frac{dy(t)}{dt} = f(t, y) = y'(t)$$

This term
decreases as Δt
decreases.

$$\frac{dy(t)}{dt} = f(t, y) = y'(t) \approx \frac{y(\Delta t + t) - y(t)}{\Delta t} - \frac{1}{2}y''(t)\Delta t$$

$$f(t, y) = \frac{y(\Delta t + t) - y(t)}{\Delta t} - \frac{1}{2}y''(t)\Delta t$$

$$y(\Delta t + t) = \Delta t f(t, y) + y(t) + \frac{1}{2}y''(t)(\Delta t)^2$$

$$= f(x = a) + \frac{df}{dx}(x = a) \times (x - a) + \frac{1}{2} \frac{d^2f}{dx^2}(x = a) \times (x - a)^2$$

$$y(x + a) = y(a) + y'(a)x + \frac{1}{2}y''(a)x^2 + \frac{1}{6}y'''(a)x^3 \dots$$

$$y(\Delta t + t) = ?$$

$$y(\Delta t + t) = y(t) + y'(t)\Delta t + \frac{1}{2}y''(t)(\Delta t)^2 + \frac{1}{6}y'''(t)(\Delta t)^3$$

$$y(\Delta t + t) = y(t) + y'(t)\Delta t + \frac{1}{2}y''(t)(\Delta t)^2$$

$$y'(t)\Delta t = y(\Delta t + t) - y(t) - \frac{1}{2}y''(t)(\Delta t)^2$$

$$y'(t) = \frac{y(\Delta t + t) - y(t)}{\Delta t} - \frac{1}{2}y''(t)\Delta t$$

$$y(\Delta t + t) = y(t) + \Delta t f(t, y)$$

$$y(t_{n+1}) = y(t_n) + \Delta t f(t_n, y_n)$$



Taylor series and Euler method

$$\frac{dy(t)}{dt} = f(t, y)$$

Let's say we have a initial state such that

$$y(t = 0) = y_0$$

$$y(t_{n+1}) = y(t_n) + \Delta t f(t_n, y_n)$$

$$y(t_{n+1}) = y(t_n) + \Delta t \frac{dy(t_n)}{dt}$$

You know exactly what $\frac{dy(t_n)}{dt}$ is.
You don't know what $y(t)$ is.

Following the Euler method, once you know $y(t = 0) = y_0$, you can obtain $y(t = \Delta t) = y_1$ and so $y(t = 2\Delta t) = y_2$, and so forth.

Provided that 1) your approximation using the Taylor expansion is reasonable; and that 2) the time increment Δt is sufficiently small.

