

# Legendre polynomials

Verify

$$(1-x^2)\frac{d^2}{dx^2}P_l^m(x) - 2x\frac{d}{dx}P_l^m(x) + \left[l(l+1) - \frac{m^2}{1-x^2}\right]P_l^m(x) = 0$$

where  $P_l^m(x)$  are associated Legendre polynomials

$$P_l^m(x) = \begin{cases} \frac{(-1)^m}{2^l l!} (1-x^2)^{m/2} \frac{d^{l+m}}{dx^{l+m}} (x^2-1)^l, & m \geq 0 \\ (-1)^m \frac{(l+m)!}{(l-m)!} P_l^{|m|}(x), & m < 0 \end{cases}$$

Legendre polynomials are needed for spherical harmonic functions  $Y_{lm}(\theta, \phi)$ .

$$Y_{lm}(\theta, \phi) = (-1)^m \sqrt{\frac{(2l+1)}{4\pi} \frac{(l-m)!}{(l+m)!}} P_l^m(\cos \theta) \exp(im\phi)$$

See [arxiv.org/abs/1805.12125](https://arxiv.org/abs/1805.12125) for the following form of  $P_l^m(\cos \theta)$ .

$$P_l^m(\cos \theta) = \begin{cases} \left(\frac{\sin \theta}{2}\right)^m \sum_{k=0}^{l-m} (-1)^k \frac{(l+m+k)!}{(l-m-k)!(m+k)!k!} \left(\frac{1-\cos \theta}{2}\right)^k, & m \geq 0 \\ (-1)^m \frac{(l+m)!}{(l-m)!} P_l^{|m|}(\cos \theta), & m < 0 \end{cases}$$