

# Associated Legendre polynomials

Verify that

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

for selected associated Legendre polynomials  $P_{lm}(x)$ .

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

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

See [arxiv.org/abs/1805.12125](https://arxiv.org/abs/1805.12125) for the following form of  $P_{lm}(\cos \theta)$ .

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