31. CLEBSCH-GORDAN COEFFICIENTS, SPHERICAL HARMONICS, AND *d* FUNCTIONS

Note: A square-root sign is to be understood over *every* coefficient, *e.g.*, for −8/15 read $-\sqrt{8/15}$.

Notation:

		J	J	...
		M	M	...
m_1	m_2	Coefficients		
m_1	m_2			
.	.			
.	.			
.	.			

$$Y_1^0 = \sqrt{\frac{3}{4\pi}}\cos\theta$$

$$Y_1^1 = -\sqrt{\frac{3}{8\pi}}\,\sin\theta\, e^{i\phi}$$

$$Y_2^0 = \sqrt{\frac{5}{4\pi}}\Big(\frac{3}{2}\cos^2\theta - \frac{1}{2}\Big)$$

$$Y_2^1 = -\sqrt{\frac{15}{8\pi}}\,\sin\theta\cos\theta\, e^{i\phi}$$

$$Y_2^2 = \frac{1}{4}\sqrt{\frac{15}{2\pi}}\,\sin^2\theta\, e^{2i\phi}$$

$$Y_\ell^{-m} = (-1)^m Y_\ell^{m*}$$

$$\langle j_1 j_2 m_1 m_2 | j_1 j_2 J M\rangle = (-1)^{J-j_1-j_2}\langle j_2 j_1 m_2 m_1 | j_2 j_1 J M\rangle$$

1/2×1/2

		1
		+1
+1/2	+1/2	1

		1	0
		0	0
+1/2	−1/2	1/2	1/2
−1/2	+1/2	1/2	−1/2

		1
		−1
−1/2	−1/2	1

1×1/2

		3/2
		+3/2
+1	+1/2	1

		3/2	1/2
		+1/2	+1/2
+1	−1/2	1/3	2/3
0	+1/2	2/3	−1/3

		3/2	1/2
		−1/2	−1/2
0	−1/2	2/3	1/3
−1	+1/2	1/3	−2/3

		3/2
		−3/2
−1	−1/2	1

2×1

		3
		+3
+2	+1	1

		3	2
		+2	+2
+2	0	1/3	2/3
+1	+1	2/3	−1/3

		3	2	1
		+1	+1	+1
+2	−1	1/15	1/3	3/5
+1	0	8/15	1/6	−3/10
0	+1	6/15	−1/2	1/10

		3	2	1
		0	0	0
+1	−1	1/5	1/2	3/10
0	0	3/5	0	−2/5
−1	+1	1/5	−1/2	3/10

		3	2	1
		−1	−1	−1
0	−1	6/15	1/2	1/10
−1	0	8/15	−1/6	−3/10
−2	+1	1/15	−1/3	3/5

		3	2
		−2	−2
−1	−1	2/3	1/3
−2	0	1/3	−2/3

		3
		−3
−2	−1	1

1×1

		2
		+2
+1	+1	1

		2	1
		+1	+1
+1	0	1/2	1/2
0	+1	1/2	−1/2

		2	1	0
		0	0	0
+1	−1	1/6	1/2	1/3
0	0	2/3	0	−1/3
−1	+1	1/6	−1/2	1/3

		2	1
		−1	−1
0	−1	1/2	1/2
−1	0	1/2	−1/2

		2
		−2
−1	−1	1

3/2×1

		5/2
		+5/2
+3/2	+1	1

		5/2	3/2
		+3/2	+3/2
+3/2	0	2/5	3/5
+1/2	+1	3/5	−2/5

		5/2	3/2	1/2
		+1/2	+1/2	+1/2
+3/2	−1	1/10	2/5	1/2
+1/2	0	3/5	1/15	−1/3
−1/2	+1	3/10	−8/15	1/6

		5/2	3/2	1/2
		−1/2	−1/2	−1/2
+1/2	−1	3/10	8/15	1/6
−1/2	0	3/5	−1/15	−1/3
−3/2	+1	1/10	−2/5	1/2

		5/2	3/2
		−3/2	−3/2
−1/2	−1	3/5	2/5
−3/2	0	2/5	−3/5

		5/2
		−5/2
−3/2	−1	1

2×1/2

		5/2
		+5/2
+2	1/2	1

		5/2	3/2
		3/2	+3/2
+2	−1/2	1/5	4/5
+1	+1/2	4/5	−1/5

		5/2	3/2
		+1/2	+1/2
+1	−1/2	2/5	3/5
0	+1/2	3/5	−2/5

		5/2	3/2
		−1/2	−1/2
0	−1/2	3/5	2/5
−1	+1/2	2/5	−3/5

		5/2	3/2
		−3/2	−3/2
−1	−1/2	4/5	1/5
−2	+1/2	1/5	−4/5

		5/2
		−5/2
−2	−1/2	1

3/2×1/2

		2
		+2
+3/2	+1/2	1

		2	1
		+1	+1
+3/2	−1/2	1/4	3/4
+1/2	+1/2	3/4	−1/4

		2	1
		0	0
+1/2	−1/2	1/2	1/2
−1/2	+1/2	1/2	−1/2

		2	1
		−1	−1
−1/2	−1/2	3/4	1/4
−3/2	+1/2	1/4	−3/4

		2
		−2
−3/2	−1/2	1

$$d^{\ell}_{m,0} = \sqrt{\frac{4\pi}{2\ell+1}}\, Y^m_\ell\, e^{-im\phi}$$

$$d^{j}_{m',m} = (-1)^{m-m'} d^{j}_{m,m'} = d^{j}_{-m,-m'}$$

$$d^{1}_{0,0} = \cos\theta \qquad d^{1/2}_{1/2,1/2} = \cos\frac{\theta}{2} \qquad d^{1}_{1,1} = \frac{1+\cos\theta}{2}$$

$$d^{1/2}_{1/2,-1/2} = -\sin\frac{\theta}{2} \qquad d^{1}_{1,0} = -\frac{\sin\theta}{\sqrt{2}}$$

$$d^{1}_{1,-1} = \frac{1-\cos\theta}{2}$$

3/2×3/2

	3	
	+3	
+3/2 +3/2	1	

	3	2	
	+2	+2	
+3/2 +1/2	1/2	1/2	
+1/2 +3/2	1/2	−1/2	

	3	2	1	
	+1	+1	+1	
+3/2 −1/2	1/5	1/2	3/10	
+1/2 +1/2	3/5	0	−2/5	
−1/2 +3/2	1/5	−1/2	3/10	

	3	2	1	0	
	0	0	0	0	
+3/2 −3/2	1/20	1/4	9/20	1/4	
+1/2 −1/2	9/20	1/4	−1/20	−1/4	
−1/2 +1/2	9/20	−1/4	−1/20	1/4	
−3/2 +3/2	1/20	−1/4	9/20	−1/4	

	3	2	1	
	−1	−1	−1	
+1/2 −3/2	1/5	1/2	3/10	
−1/2 −1/2	3/5	0	−2/5	
−3/2 +1/2	1/5	−1/2	3/10	

	3	2	
	−2	−2	
−1/2 −3/2	1/2	1/2	3
−3/2 −1/2	1/2	−1/2	−3

−3/2	−3/2	1

2×3/2

	7/2	
	+7/2	
+2 +3/2	1	

	7/2	5/2	
	+5/2	+5/2	
+2 +1/2	3/7	4/7	
+1 +3/2	4/7	−3/7	

	7/2	5/2	3/2	
	+3/2	+3/2	+3/2	
+2 −1/2	1/7	16/35	2/5	
+1 1/2	4/7	1/35	−2/5	
0 3/2	2/7	−18/35	1/5	

	7/2	5/2	3/2	1/2	
	+1/2	+1/2	+1/2	+1/2	
+2 −3/2	1/35	6/35	2/5	2/5	
+1 −1/2	12/35	5/14	0	−3/10	
0 1/2	18/35	−3/35	−1/5	1/5	
−1 3/2	4/35	−27/70	2/5	−1/10	

	7/2	5/2	3/2	1/2	
	−1/2	−1/2	−1/2	−1/2	
+1 −3/2	4/35	27/70	2/5	1/10	
0 −1/2	18/35	3/35	−1/5	−1/5	
−1 1/2	12/35	−5/14	0	3/10	
−2 3/2	1/35	−6/35	2/5	−2/5	

	7/2	5/2	3/2	
	−3/2	−3/2	−3/2	
0 −3/2	2/7	18/35	1/5	
−1 −1/2	4/7	−1/35	−2/5	
−2 1/2	1/7	−16/35	2/5	

	7/2	5/2	
	−5/2	−5/2	
−1 −3/2	4/7	3/7	7/2
−2 −1/2	3/7	−4/7	−7/2

−2	−3/2	1

2×2

	4	
	4	
+2 +2	1	

	4	3	
	+3	+3	
+2 +1	1/2	1/2	
+1 +2	1/2	−1/2	

	4	3	2	
	+2	+2	+2	
+2 0	3/14	1/2	2/7	
+1 1	4/7	0	−3/7	
0 2	3/14	−1/2	2/7	

	4	3	2	1	
	+1	+1	+1	+1	
+2 −1	1/14	3/10	3/7	1/5	
+1 0	3/7	1/5	−1/14	−3/10	
0 1	3/7	−1/5	−1/14	3/10	
−1 2	1/14	−3/10	3/7	−1/5	

	4	3	2	1	0	
	0	0	0	0	0	
+2 −2	1/70	1/10	2/7	2/5	1/5	
+1 −1	8/35	2/5	1/14	−1/10	−1/5	
0 0	18/35	0	−2/7	0	1/5	
−1 1	8/35	−2/5	1/14	1/10	−1/5	
−2 2	1/70	−1/10	2/7	−2/5	1/5	

	4	3	2	1	
	−1	−1	−1	−1	
+1 −2	1/14	3/10	3/7	1/5	
0 −1	3/7	1/5	−1/14	−3/10	
−1 0	3/7	−1/5	−1/14	3/10	
−2 1	1/14	−3/10	3/7	−1/5	

	4	3	2	
	−2	−2	−2	
0 −2	3/14	1/2	2/7	
−1 −1	4/7	0	−3/7	
−2 0	3/14	−1/2	2/7	

	4	3	
	−3	−3	
−1 −2	1/2	1/2	4
−2 −1	1/2	−1/2	−4

−2	−2	1

$$d^{3/2}_{3/2,3/2} = \frac{1+\cos\theta}{2}\cos\frac{\theta}{2}$$

$$d^{3/2}_{3/2,1/2} = -\sqrt{3}\frac{1+\cos\theta}{2}\sin\frac{\theta}{2} \qquad d^{2}_{2,2} = \left(\frac{1+\cos\theta}{2}\right)^2$$

$$d^{3,2}_{3/2,-1/2} = \sqrt{3}\frac{1-\cos\theta}{2}\cos\frac{\theta}{2} \qquad d^{2}_{2,1} = -\frac{1+\cos\theta}{2}\sin\theta$$

$$d^{3,2}_{3/2,-3/2} = -\frac{1-\cos\theta}{2}\sin\frac{\theta}{2} \qquad d^{2}_{2,0} = \frac{\sqrt{6}}{4}\sin^2\theta \qquad d^{2}_{1,1} = \frac{1+\cos\theta}{2}(2\cos\theta - 1)$$

$$d^{3/2}_{1/2,1/2} = \frac{3\cos\theta - 1}{2}\cos\frac{\theta}{2} \qquad d^{2}_{2,-1} = -\frac{1-\cos\theta}{2}\sin\theta \qquad d^{2}_{1,0} = -\sqrt{\frac{3}{2}}\sin\theta\,\cos\theta$$

$$d^{3/2}_{1/2,-1/2} = -\frac{3\cos\theta + 1}{2}\sin\frac{\theta}{2} \qquad d^{2}_{2,-2} = \left(\frac{1-\cos\theta}{2}\right)^2 \qquad d^{2}_{1,-1} = \frac{1-\cos\theta}{2}(2\cos\theta + 1) \qquad d^{2}_{0,0} = \left(\frac{3}{2}\cos^2\theta - \frac{1}{2}\right)$$