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			
.	.			

1/2×1/2

m_1	m_2			
	J	1		
	M	+1		
+1/2	+1/2	1		
	J	1	0	
	M	0	0	
+1/2	−1/2	1/2	1/2	
−1/2	+1/2	1/2	−1/2	
	J	1		
	M	−1		
−1/2	−1/2	1		

1×1/2

m_1	m_2		
	J	3/2	
	M	+3/2	
+1	+1/2	1	
	J	3/2	1/2
	M	+1/2	+1/2
+1	−1/2	1/3	2/3
0	+1/2	2/3	−1/3
	J	3/2	1/2
	M	−1/2	−1/2
0	−1/2	2/3	1/3
−1	+1/2	1/3	−2/3
	J	3/2	
	M	−3/2	
−1	−1/2	1	

2×1/2

m_1	m_2		
	J	5/2	
	M	+5/2	
+2	1/2	1	
	J	5/2	3/2
	M	+3/2	+3/2
+2	−1/2	1/5	4/5
+1	+1/2	4/5	−1/5
	J	5/2	3/2
	M	+1/2	+1/2
+1	−1/2	2/5	3/5
0	+1/2	3/5	−2/5
	J	5/2	3/2
	M	−1/2	−1/2
0	−1/2	3/5	2/5
−1	+1/2	2/5	−3/5
	J	5/2	3/2
	M	−3/2	−3/2
−1	−1/2	4/5	1/5
−2	+1/2	1/5	−4/5
	J	5/2	
	M	−5/2	
−2	−1/2	1	

3/2×1/2

m_1	m_2		
	J	2	
	M	+2	
+3/2	+1/2	1	
	J	2	1
	M	+1	+1
+3/2	−1/2	1/4	3/4
+1/2	+1/2	3/4	−1/4
	J	2	1
	M	0	0
+1/2	−1/2	1/2	1/2
−1/2	+1/2	1/2	−1/2
	J	2	1
	M	−1	−1
−1/2	−1/2	3/4	1/4
−3/2	+1/2	1/4	−3/4
	J	2	
	M	−2	
−3/2	−1/2	1	

2×1

m_1	m_2			
	J	3		
	M	+3		
+2	+1	1		
	J	3	2	
	M	+2	+2	
+2	0	1/3	2/3	
+1	+1	2/3	−1/3	
	J	3	2	1
	M	+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
	J	3	2	1
	M	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
	J	3	2	1
	M	−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
	J	3	2	
	M	−2	−2	
−1	−1	2/3	1/3	
−2	0	1/3	−2/3	
	J	3		
	M	−3		
−2	−1	1		

3/2×1

m_1	m_2			
	J	5/2		
	M	+5/2		
+3/2	+1	1		
	J	5/2	3/2	
	M	+3/2	+3/2	
+3/2	0	2/5	3/5	
+1/2	+1	3/5	−2/5	
	J	5/2	3/2	1/2
	M	+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
	J	5/2	3/2	1/2
	M	−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
	J	5/2	3/2	
	M	−3/2	−3/2	
−1/2	−1	3/5	2/5	
−3/2	0	2/5	−3/5	
	J	5/2		
	M	−5/2		
−3/2	−1	1		

1×1

m_1	m_2			
	J	2		
	M	+2		
+1	+1	1		
	J	2	1	
	M	+1	+1	
+1	0	1/2	1/2	
0	+1	1/2	−1/2	
	J	2	1	0
	M	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
	J	2	1	
	M	−1	−1	
0	−1	1/2	1/2	
−1	0	1/2	−1/2	
	J	2		
	M	−2		
−1	−1	1		

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

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

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

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

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

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

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

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

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

2×3/2

m_1	m_2				
	J	7/2			
	M	+7/2			
+2	+3/2	1			
	J	7/2	5/2		
	M	+5/2	+5/2		
+2	+1/2	3/7	4/7		
+1	+3/2	4/7	−3/7		
	J	7/2	5/2	3/2	
	M	+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	
	J	7/2	5/2	3/2	1/2
	M	+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
	J	7/2	5/2	3/2	1/2
	M	−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
	J	7/2	5/2	3/2	
	M	−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	
	J	7/2	5/2		
	M	−5/2	−5/2		
−1	−3/2	4/7	3/7		
−2	−1/2	3/7	−4/7		
	J	7/2			
	M	−7/2			
−2	−3/2	1			

3/2×3/2

m_1	m_2				
	J	3			
	M	+3			
+3/2	+3/2	1			
	J	3	2		
	M	+2	+2		
+3/2	+1/2	1/2	1/2		
+1/2	+3/2	1/2	−1/2		
	J	3	2	1	
	M	+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	
	J	3	2	1	0
	M	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
	J	3	2	1	
	M	−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	
	J	3	2		
	M	−2	−2		
−1/2	−3/2	1/2	1/2		
−3/2	−1/2	1/2	−1/2		
	J	3			
	M	−3			
−3/2	−3/2	1			

2×2

m_1	m_2					
	J	4				
	M	4				
+2	+2	1				
	J	4	3			
	M	+3	+3			
+2	+1	1/2	1/2			
+1	+2	1/2	−1/2			
	J	4	3	2		
	M	+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		
	J	4	3	2	1	
	M	+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	
	J	4	3	2	1	0
	M	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
	J	4	3	2	1	
	M	−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	
	J	4	3	2		
	M	−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		
	J	4	3			
	M	−3	−3			
−1	−2	1/2	1/2			
−2	−1	1/2	−1/2			
	J	4				
	M	−4				
−2	−2	1				

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

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

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

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

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

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

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

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

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

Figure 31.1: The sign convention is that of Wigner (*Group Theory*, Academic Press, New York, 1959), also used by Condon and Shortley (*The Theory of Atomic Spectra*, Cambridge Univ. Press, New York, 1953), Rose (*Elementary Theory of Angular Momentum*, Wiley, New York, 1957), and Cohen (*Tables of the Clebsch-Gordan Coefficients*, North American Rockwell Science Center, Thousand Oaks, Calif., 1974). The coefficients here have been calculated using computer programs written independently by Cohen and at LBNL.