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"Good" Fundamental Material Constants for Crystalline Quartz

Constant	Value	Reference
Composition	Silicon 46.72% by weight Oxygen 53.28% by weight	Sosman (1927)

Conductivity, Thermal

Parallel	Perpendicular	Temperature	Reference
—	0.68	-252 °C	Sosman (1927)
0.117	0.0586	-190 °C	
0.476	0.02409	-78	
0.0325	0.01731	0	
0.0215	0.01333	100	
0.029	0.016	20	Frondel (1962)
	cal / cm / s / °C		

Constant	Value	Reference
Curie Temperature (low-high inversion, alpha-beta inversion)	573.3°C	Cady (1964) Frondel (1962) Sosman (1927)
Density, absolute	2.65067 g/cm^3 2.64822 g/cm^3	Cady (1964) Bechmann, Ballato, Lukaszek (1962) Bottom (1970) Frondel (1962) Sosman (1927)

Dielectric Constant

Value	Reference
4.6 Parallel to Z-axis	Sosman (1927)
4.60	Bottom (1970)
4.5 Perpendicular to Z-axis	Sosman (1927)
4.51	Bottom (1970)
- also see Cady (1964) and Frondel (1962)	
$e_{11}^T = e_{22}^T = 39.97\text{x}10^{-12}$ F/m	Bechmann, Ballato, Lukaszek (1962)
$e_{11}^S - e_{22}^T = -0.76$	
$e_{33}^T = 41.03$	
$e_{33}^S - e_{33}^T = 0$	

Temperature Coefficient

Parallel: $K = 4.926[1-1.10\text{x}10^{-3}(T-10) - 2.4\text{x}10^{-5}(T-10)^2]$ Sosman (1927)

Perpendicular: $K = 4.766[1-9.9\text{x}10^{-4}(T-10)]$ for T = 10—31°C

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Elastic Coefficients, Third Order		Thurston (1996)
	C111 = - 2.10x10^{12} dyn/cm^2	
	C112 = - 3.45x10^{12} dyn/cm^2	
	C113 = + 0.12x10^{12} dyn/cm^2	
	C114 = - 1.63x10^{12} dyn/cm^2	
	C123 = - 2.94x10^{12} dyn/cm^2	
	C124 = - 0.15x10^{12} dyn/cm^2	
	C133 = - 3.12x10^{12} dyn/cm^2	
	C134 = + 0.02x10^{12} dyn/cm^2	
	C144 = - 1.34x10^{12} dyn/cm^2	
	C155 = - 2.00x10^{12} dyn/cm^2	
	C222 = - 3.32x10^{12} dyn/cm^2	
	C333 = - 8.15x10^{12} dyn/cm^2	
	C344 = - 1.10x10^{12} dyn/cm^2	
	C444 = - 2.76x10^{12} dyn/cm^2	
Hardness, penetration MHO	7	Sosman (1927)
Lattice Constant	4.9134 Å @ 25°C, cultured	Brice (1980)
Piezoelectric Coefficients		
	d11 = - 2.30x10^{-12} m/V	Sosman (1927)
	d11 = - 2.27x10^{-12} m/V	Bottom (1970)
	d11 = - 2.25x10^{-12} m/V	Heising (1946)
	d11 = - 2.30x10^{-12} m/V	Cady (1964)
	d14 = 0.57x10^{-12} m/V	Sosman (1927)
	d14 = 0.85x10^{-12} m/V	Heising (1946)
	d14 = 0.67x10^{-12} m/V	Cady (1964)
Note: 1 esu/dyne = 3 x 10^4 m/V		
	d11 = 2.32x10-12 m/V @ 1.5°K	Graham (1971)
	d11 = 2.32x10-12 m/V @ 4.2°K	
	d11 = 2.31x10-12 m/V @ - 196°C	
	d11 = 2.22x10-12 m/V @ 20°C	
	d11 = 2.05x10-12 m/V @ 100°C	

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Piezoelectric Coefficients

	Stress	
e11 =	0.171 C/m^2	Bechmann, Ballato, Lukaszek (1962)
e11 =	0.180 C/m^2	Cady (1964)
e14 =	0.0403 C/m^2	Bechmann, Ballato, Lukaszek (1962)
e14 =	0.04 C/m^2	Cady (1964)

Refractive Index

Ordinary Ray

$n_o^2 = 3.4269 + 1.0654\text{x}10^{-2} / (L^2 - 0.010627) + 111.49 / (L^2 - 100.77)$ Sosman (1927)

$n_o^2 = 3.53445 + 0.008067 / (L^2 - 0.0127493) + 0.002682 / (L^2 - 0.000974) + 127.2 / (L^2 - 108)$ Frondel (1962)

Extraordinary Ray

$n_e^2 = 3.5612557 + 0.00844614 / (L^2 - 0.0127493) + 0.00276113 / (L^2 - 0.000974) + 127.2 / (L^2 - 108)$ Frondel (1962)

where L = wavelength in µm

n_o =	1.54425 (Na @ 18°C)	Cady (1964)
n_e =	155336	

Temperature Coefficient

Ordinary Ray: - 6.50x10-6 / °C	Frondel (1962)
Extraordinary Ray: - 7.544	Sosman (1927)

Stiffness

	C^D	C^E	
C_{11} =	87.49	86.74x10^9 N/m^2	Bechmann, Ballato, Lukaszek (1962)
C_{13} =	11.91	11.9174x10^9 N/m^2	
C_{33} =	107.2	107.274x10^9 N/m^2	
C_{14} =	- 18.09	- 17.9174x10^9 N/m^2	
C_{44} =	57.98	57.9474x10^9 N/m^2	
C_{66} =	40.63	39.8874x10^9 N/m^2	

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Stiffness

Temperature Coefficient

ij	First $x10^{-6} / ^\circ C$	Second $x10^{-9} / ^\circ C$	Third $x10^{-12} / ^\circ C^2$	
				Bechmann, Ballato, Lukaszek (1962)
11	- 48.5	- 107	- 70	Adams, Enslow, Kusters, Ward (1970)
	- 49.6	-107	- 74	
13	- 550	-1150	- 750	
	- 651	- 1021	- 240	
33	- 160	- 275	- 250	
	- 192	- 162	67	
14	101	- 48	- 590	
	89	- 19	- 521	
44	- 177	- 216	- 216	
	- 172	- 261	- 194	
66	178	118	21	
	167	164	29	

Thermal Expansion Coefficient, Linear (Mean, from 0 °C)

Parallel	Perpendicular	Temperature	
$4.10x10^{-6} / ^\circ C$	$8.60x10^{-6} / ^\circ C$	- 250 °C	Sosman (1927)
$5.50x10^{-6} / ^\circ C$	$9.90x10^{-6} / ^\circ C$	- 200°C	
$6.08x10^{-6} / ^\circ C$	$11.82x10^{-6} / ^\circ C$	- 100°C	
$7.10x10^{-6} / ^\circ C$	$13.24x10^{-6} / ^\circ C$	0°C	
$7.97x10^{-6} / ^\circ C$	$14.45x10^{-6} / ^\circ C$	100°C	
$8.75x10^{-6} / ^\circ C$	$15.61x10^{-6} / ^\circ C$	200°C	
$9.60x10^{-6} / ^\circ C$	$16.89x10^{-6} / ^\circ C$	300°C	
$10.65x10^{-6} / ^\circ C$	$18.50x10^{-6} / ^\circ C$	400°C	
$12.22x10^{-6} / ^\circ C$	$20.91x10^{-6} / ^\circ C$	500°C	
$15.00x10^{-6} / ^\circ C$	$25.15x10^{-6} / ^\circ C$	573°C	

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TEMPERATURE COEFFICIENT

ij	First	Second	Third	
	$x10^{-6}$ / °C	$x10^{-9}$ / °C	$x10^{-12}$ / °C^2	Bechmann, Ballato, Lukaszek (1962) Kosinski, Gualtieri, Ballato (1996)
11	13.71	605	- 1.9	
33	7.48	2.9	- 1.5	

Note: $a_{11} = a_{22}$

YOUNG'S MODULUS

$1.03x10^{12}$ dynes / cm^2 Parallel — Cady (1964)

0.78 Perpendicular

$S'_{33}x10^{15} = 1269 - 841 \cos^2\Theta + 543 \cos^4\Theta - 862 \sin^3\Theta \cos\Theta \sin^3ø$ cm^2 / dyne

Frondel (1962) Corrected
(Note: Eq. In Frondel has extra term due to typo and incorrect power of 10)

Note: $Y_m = 1 / S'_{33}$

Note: Parallel = Parallel to Z-axis (Optical Axis)
Perpendicular = Perpendicular to Z-axis

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