

References (database v3.1, 12.10.2016)

References for the thermal, physical, and dielectric properties listed in our material properties database. Values for tissues of which the properties are not available in the literature are substituted with values from other tissues. In these cases, the tissue used for the value is listed instead of a reference. The rationale for each individual substitution is provided in the Rationale for Tissue Substitutions.

Tissue	Density	Heat Capacity	Thermal Conductivity	Heat Transfer Rate	Dielectric Properties
Adrenal Gland	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Bernardi et al., 2003	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Peyman et al., 2012
Air	N/A See Fluid Properties Database, Equation	Bernardi et al., 2003 Collins et al., 2004 See Fluid Properties Database, Equation	Bernardi et al., 2003 Collins et al., 2004 See Fluid Properties Database, Equation	Not in Database	Gabriel et al., 1996
Bile	McIntosh and Anderson, 2010	Bernardi et al., 2003 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Gabriel et al., 1996
Blood	Duck, 1990 McIntosh and Anderson, 2010	Bernardi et al., 2003 McIntosh and Anderson, 2010	Collins et al., 2004 Duck, 1990 Holmes Appendix A-B McIntosh and Anderson, 2010 Van Den Berg et al., 1983	Collins et al., 2004	Gabriel et al., 1996
Blood Plasma	Hinghofer-Szalansky et al., 1987	Duck, 1990	Duck, 1990	Not in Database	Not in Database
Blood Serum	Wolf, 2000	Not in Database	Not in Database	Not in Database	Not in Database
Blood Vessel Wall	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Williams et al., 1988	Gabriel et al., 1996

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Tissue	Density	Heat Capacity	Thermal Conductivity	Heat Transfer Rate	Dielectric Properties
Bone	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)
Bone (Cancellous)	Duck, 1990 McIntosh and Anderson, 2010	Collins et al., 2004 McIntosh and Anderson, 2010	Clattenburg et al., 1975 Collins et al., 2004 McIntosh and Anderson, 2010	Collins et al., 2004 McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996
Bone (Cortical)	Duck, 1990 McIntosh and Anderson, 2010	Duck, 1990 McIntosh and Anderson, 2010 Van Leeuwen et al., 1999	Collins et al., 2004 McIntosh and Anderson, 2010	Collins et al., 2004	Gabriel et al., 1996
Bone Marrow (Red)	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996
Bone Marrow (Yellow)	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Gabriel et al., 1996
Brain	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Cerebellum
Brain (Grey Matter)	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Bernardi et al., 2003 Duck, 1990	McIntosh and Anderson, 2010	Collins et al., 2004 McIntosh and Anderson, 2010	Gabriel et al., 1996
Brain (White Matter)	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Duck, 1990 Bernardi et al., 2003	McIntosh and Anderson, 2010	Collins et al., 2004 McIntosh and Anderson, 2010	Gabriel et al., 1996
Breast Fat	Fat	Fat	Hamilton, 1998	Delille et al., 2002	Gabriel et al., 1996
Breast Gland	McIntosh and Anderson, 2010 Woodard et al., 1986	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Thyroid Gland

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Tissue	Density	Heat Capacity	Thermal Conductivity	Heat Transfer Rate	Dielectric Properties
Bronchi	Blood Vessel Wall	Blood Vessel Wall	Blood Vessel Wall	Parsons et al., 1985 Wu et al., 1985	Trachea
Bronchi lumen	Air	Air	Air	None	Air
Cartilage	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Bernardi et al., 2003	McIntosh and Anderson, 2010 Bernardi et al., 2003	McIntosh and Anderson, 2010	Gabriel et al., 1996
Cerebellum	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Gabriel et al., 1996
Cerebrospinal Fluid	Duck, 1990	Bernardi et al., 2003 Van Leeuwen et al., 1999	Collins et al., 2004 Van Leeuwen et al., 1999 Bernardi et al., 2003	None	Gabriel et al., 1996
Cervix	Uterus	Uterus	Uterus	N/A	Gabriel et al., 1996
Commissura Anterior	Brain (White Matter)	Brain (White Matter)	Brain (White Matter)	Brain (White Matter)	Brain (White Matter)
Commissura Posterior	Brain (White Matter)	Brain (White Matter)	Brain (White Matter)	Brain (White Matter)	Brain (White Matter)
Connective Tissue	Tendon/Ligament and Bone (Cortical)	Tendon/Ligament and Bone (Cortical)	Tendon/Ligament and Bone (Cortical)	N/A	Tendon\Ligament
Diaphragm	Muscle	Muscle	Muscle	Guenette et al., 1985	Muscle
Ductus Deferens	Blood Vessel Wall	Blood Vessel Wall	Blood Vessel Wall	Ureter/Urethra	Blood Vessel Wall
Dura	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Gabriel et al., 1996
Epididymis	Testis	Testis	Testis	Testis	Testis
Esophagus	Duck, 1990	McIntosh et al., 2010	Collins et al., 2004	Barnes et al., 1983	Stomach
Esophagus Lumen	Air	Air	Air	None	Air
Eye (Cornea)	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Bernardi et al., 2003	None	Gabriel et al., 1996
Eye (Lens)	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Bernardi et al., 2003 Van Leeuwen et al., 1999	McIntosh and Anderson, 2010 Oezen et al. Bernardi et al., 2003	None	Gabriel et al., 1996
Eye (Sclera)	N/A	Bernardi et al., 2003	Bernardi et al., 2003	McIntosh and Anderson, 2010	Gabriel et al., 1996

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Tissue	Density	Heat Capacity	Thermal Conductivity	Heat Transfer Rate	Dielectric Properties
Eye (Vitrous Humor)	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Collins et al., 2004 Van Leeuwen et al., 1999	McIntosh and Anderson, 2010 Duck, 1990 Collins et al., 2004 Oezen et al. Van Leeuwen et al., 1999	None	Gabriel et al., 1996
Eye Lens (Cortex)	Eye(Lens)	Eye(Lens)	Eye(Lens)	None	Gabriel et al., 1996
Eye Lens (Nucleus)	Eye(Lens)	Eye(Lens)	Eye(Lens)	None	Gabriel et al., 1996
Fat	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Van Den Berg et al., 1983 Collins et al., 2004 Van Leeuwen et al., 1999	McIntosh and Anderson, 2010 Duck, 1990 Holmes Appendix A-B Van Leeuwen et al., 1999	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Fat (Average Infiltrated)
Fat (Average Infiltrated)	Fat	Fat	Fat	Fat	Gabriel et al., 1996
Fat (Not Infiltrated)	Fat	Fat	Fat	None	Gabriel et al., 1996
Gallbladder	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Gabriel et al., 1996
Glandula Vesiculosa	Prostate	Prostate	Prostate	Prostate	Testis
Heart Lumen	Blood	Blood	Blood	Blood	Blood
Heart Muscle	Duck, 1990 McIntosh and Anderson, 2010	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Duck, 1990 Van Den Berg et al., 1983 Bowman et al., 1975 Holmes Appendix A-B	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996
Hippocampus	Brain (Grey Matter)	Brain (Grey Matter)	Brain (Grey Matter)	Brain (Grey Matter)	Brain (Grey Matter)

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Tissue	Density	Heat Capacity	Thermal Conductivity	Heat Transfer Rate	Dielectric Properties
Hypophysis	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Thyroid Gland
Hypothalamus	Brain (Grey Matter)	Brain (Grey Matter)	Brain (Grey Matter)	Brain (Grey Matter)	Brain (Grey Matter)
Intervertebral Disc	Cartilage	Cartilage	Cartilage	Cartilage	Peyman et al., 2010
Kidney	Duck, 1990 McIntosh and Anderson, 2010	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996
Kidney (Cortex)	McIntosh and Anderson, 2010	Holmes et al., 1983	Hamilton, 1998 McIntosh and Anderson, 2010	De Bazelaire et al., 2005 Holmes Appendix A-B Roberts et al., 1995	Kidney
Kidney (Medulla)	Duck, 1990	N/A	Bernardi et al., 2003	Holmes Appendix A-B Roberts et al., 1995	Kidney
Large Intestine	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Bernardi et al., 2003	McIntosh and Anderson, 2010 Bernardi et al., 2003 Duck, 1990	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996
Large Intestine Lumen	Muscle and Water	Muscle and Water	Muscle and Water	None	Muscle
Larynx	Cartilage	Cartilage	Cartilage	Cartilage	Cartilage
Liver	Duck, 1990 McIntosh and Anderson, 2010	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Bowman et al., 1975 Duck, 1990 Holmes Appendix A-B	Williams and Leggett, 1986 McIntosh and Anderson, 2010	Gabriel et al., 1996
Lung	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Duck, 1990 McIntosh and Anderson, 2010	Williams and Leggett, 1986	Lung (Inflated)
Lung (Deflated)	Duck, 1990	Lung	Lung	Lung	Gabriel et al., 1996

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Tissue	Density	Heat Capacity	Thermal Conductivity	Heat Transfer Rate	Dielectric Properties
Lung (Inflated)	Lung	Lung	Lung	Lung	Gabriel et al., 1996
Lymph	biowater.com	Not in Database	Not in Database	Not in Database	Not in Database
Lymphnode	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Van Den Berg et al., 1983	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Peyman et al., 2012
Mandible	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)	N/A	Bone (Cortical)
Medulla Oblongata	Brain	Brain	Brain	Brain	Cerebellum
Meniscus	Cartilage	Cartilage	Cartilage	Cartilage	Cartilage
Midbrain	Brain	Brain	Brain	Brain	Cerebellum
Mucous Membrane	N/A	Collins et al., 2004	Collins et al., 2004	McIntosh and Anderson, 2010	Muscle
Muscle	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Van Den Berg et al., 1983 Van Leeuwen et al., 1999	McIntosh and Anderson, 2010 Duck, 1990 Collins et al., 2004 Bowman et al., 1975 Van Leeuwen et al., 1999	McIntosh and Anderson, 2010 Sekins et al., 1980 Williams and Leggett, 1986	Gabriel et al., 1996
Nerve	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Gabriel et al., 1996
Ovary	Duck, 1990	Testis	Testis	N/A	Gabriel et al., 1996
Pancreas	Duck, 1990 McIntosh and Anderson, 2010	McIntosh et al., 2010	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Thyroid Gland
Patella	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)
Penis	Blood Vessel Wall	Blood Vessel Wall	Blood Vessel Wall	Joeng et al., 2002	Blood Vessel Wall
Pharynx	Air	Air	Air	None	Gabriel et al., 1996
Pineal Body	Hypophysis	Hypophysis	Hypophysis	Hypophysis	Thyroid gland
Placenta	Duck, 1990 Chung and Park, 2002	Hand et al., 2010	N/A	Duncan et al., 1998 Wagner et al., 1980	Blood

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Tissue	Density	Heat Capacity	Thermal Conductivity	Heat Transfer Rate	Dielectric Properties
Pons	Brain	Brain	McIntosh and Anderson, 2010	Brain	Cerebellum
Prostate	Duck, 1990	Giering et al., 1995	N/A	N/A	Testis
Salivary Gland	Prostate	Prostate	Prostate	Bisdas et al., 2007 Williams and Leggett, 1986	Peyman et al., 2012
SAT (Subcutaneous Fat)	Fat	Fat	Fat	Fat	Fat (Average Infiltrated)
Skin	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Collins et al., 2004 Bernardi et al., 2003 Van Leeuwen et al., 1999	McIntosh and Anderson, 2010 Duck, 1990 Collins et al., 2004 Bowman et al., 1975 Holmes Appendix A-B Van Leeuwen et al., 1999	Collins et al., 2004 McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996 (Skin Dry)
Skull (Cancellous)	Bone (Cancellous)	Bone (Cancellous)	Bone (Cancellous)	Bone (Cancellous)	Bone (Cancellous)
Skull (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)
Small Intestine	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996
Small Intestine Lumen	Muscle and Water	Muscle and Water	Muscle and Water	None	Muscle
Spinal Cord	Nerve	Brain	Brain	McIntosh and Anderson, 2010	Nerve
Spleen	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996
Stomach	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996
Stomach Lumen	Muscle and Water	Muscle and Water	Muscle and Water	None	Muscle
Tendon\Ligament	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Collins et al., 2004	McIntosh and Anderson, 2010 Collins et al., 2004	McIntosh and Anderson, 2010	Gabriel et al., 1996
Testis	Duck, 1990	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Gabriel et al., 1996

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Testis	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996
Thalamus	Brain (Grey Matter)	Brain (Grey Matter)	McIntosh et al., 2010	N/A	Brain (Grey Matter)
Thymus	N/A	Lymphnode and Fat	Lymphnode and Fat	Lymphnode and Fat	Gabriel et al., 1996
Thyroid Gland	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996
Tongue	Muscle	Muscle	Muscle	Nakase et al., 2004	Gabriel et al., 1996
Tooth	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	None	Bone (Cortical)
Tooth (Dentine)	McIntosh and Anderson, 2010	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	None	Bone (Cortical)
Tooth (Enamel)	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	None	Bone (Cortical)
Trachea	Duck, 1990	Cartilage	Cartilage	Cartilage	Gabriel et al., 1996
Trachea Lumen	Air	Air	Air	None	Air
Ureter/Urethra	Blood Vessel Wall	Blood Vessel Wall	Blood Vessel Wall	John et al., 2002	Blood Vessel Wall
Urinary Bladder Wall	Duck, 1990 McIntosh and Anderson, 2010	Bernardi et al., 2003 McIntosh and Anderson, 2010 Van Den Berg et al., 1983	Bernardi et al., 2003 Bowman et al., 1975 McIntosh and Anderson, 2010 Van Den Berg et al., 1983	Williams and Leggett, 1986	Gabriel et al., 1996
Urine	McIntosh and Anderson, 2010 Wein, Urology, Vol. 10	Water	McIntosh and Anderson, 2010	None	Peyman et al., 2012
Uterus	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Olsrud et al., 1998	N/A	Gabriel et al., 1996
Vagina	Large Intestine	Large Intestine	Large Intestine	Wagner et al., 1980	Large Intestine
Vertebrae	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)
Water	Kell, 1975	Vaxasoftware	Engineering Toolbox Hyperphysics	None	Buchner et al., 1999

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