

References (database v5.0, 21.08.2025)

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	Heat Capacity	Thermal Conductivity	Heat Transfer Rate	Dielectric Properties
Adrenal Gland	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	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	Bernardi et al., 2003 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Gabriel et al., 1996
Blood	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	Duck, 1990	Duck, 1990	Not in Database	Not in Database
Blood Serum	Not in Database	Not in Database	Not in Database	Not in Database
Blood Vessel Wall	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Williams et al., 1988	Gabriel et al., 1996

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

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Tissue	Heat Capacity	Thermal Conductivity	Heat Transfer Rate	Dielectric Properties
Bronchi	Blood Vessel Wall	Blood Vessel Wall	Parsons et al., 1985 Wu et al., 1985	Trachea
Bronchi lumen	Air	Air	None	Air
Cartilage	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	Gabriel et al., 1996
Cerebrospinal Fluid	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	N/A	Gabriel et al., 1996
Commissura Anterior	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)
Connective Tissue	Tendon/Ligament and Bone (Cortical)	Tendon/Ligament and Bone (Cortical)	N/A	Tendon\Ligament
Diaphragm	Muscle	Muscle	Guenette et al., 1985	Muscle
Ductus Deferens	Blood Vessle Wall	Blood Vessle Wall	Ureter/Urethra	Blood Vessel Wall
Dura	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Gabriel et al., 1996
Epididymis	Testis	Testis	Testis	Testis
Esophagus	McIntosh et al., 2010	Collins et al., 2004	Barnes et al., 1983	Stomach
Esophagus Lumen	Air	Air	None	Air
Extracellular Fluids	Duck, 1990	Duck, 1990	None	Cerebrospinal Fluid
Eye (Aqueous Humor)	Scott, 1998	Duck, 1990	None	Cerebrospinal Fluid
Eye (Choroid)	Blood	Xuan et al., 1999	Caprioli et al., 1984	Blood
Eye (Ciliary Body)	Muscle	Muscle	Caprioli et al., 1984	Muscle

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Tissue	Heat Capacity	Thermal Conductivity	Heat Transfer Rate	Dielectric Properties
Eye (Cornea)	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Bernardi et al., 2003	None	Gabriel et al., 1996
Eye (Iris)	Muscle	Muscle	Caprioli et al., 1984	Muscle
Eye (Lens)	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 (Retina)	Brain (Grey Matter)	Brain (Grey Matter)	Caprioli et al., 1984	Brain (Grey Matter)
Eye (Sclera)	Bernardi et al., 2003	Bernardi et al., 2003	McIntosh and Anderson, 2010	Gabriel et al., 1996
Eye Lens (Cortex)	Eye(Lens)	Eye(Lens)	None	Gabriel et al., 1996
Eye Lens (Nucleus)	Eye(Lens)	Eye(Lens)	None	Gabriel et al., 1996
Fat	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	Gabriel et al., 1996
Fat (Not Infiltrated)	Fat	Fat	None	Gabriel et al., 1996
Gallbladder	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Gabriel et al., 1996
Glandula Vesiculosa	Prostate	Prostate	Prostate	Testis
Heart Lumen	Blood	Blood	Blood	Blood

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Tissue	Heat Capacity	Thermal Conductivity	Heat Transfer Rate	Dielectric Properties
Heart Muscle	Duck, 1990 McIntosh and Anderson, 2010	Duck, 1990 McIntosh and Anderson, 2010 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
Hypophysis	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)
Intervertebral Disc	Cartilage	Cartilage	Cartilage	Peyman et al., 2010
Kidney	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996
Kidney (Cortex)	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)	N/A	Bernardi et al., 2003	Holmes Appendix A-B Roberts et al., 1995	Kidney
Large Intestine	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	None	Muscle
Larynx	Cartilage	Cartilage	Cartilage	Cartilage
Liver	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	McIntosh and Anderson, 2010	Duck, 1990 McIntosh and Anderson, 2010	Williams and Leggett, 1986	Lung (Inflated)

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Tissue	Heat Capacity	Thermal Conductivity	Heat Transfer Rate	Dielectric Properties
Lung (Deflated)	Lung	Lung	Lung	Gabriel et al., 1996
Lung (Inflated)	Lung	Lung	Lung	Gabriel et al., 1996
Lymph	Not in Database	Not in Database	Not in Database	Not in Database
Lymphnode	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)	N/A	Bone (Cortical)
Medulla Oblongata	Brain	Brain	Brain	Cerebellum
Meniscus	Cartilage	Cartilage	Cartilage	Cartilage
Midbrain	Brain	Brain	Brain	Cerebellum
Mucous Membrane	Collins et al., 2004	Collins et al., 2004	McIntosh and Anderson, 2010	Muscle
Muscle	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	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Gabriel et al., 1996
Ovary	Testis	Testis	N/A	Gabriel et al., 1996
Pancreas	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)
Penis	Blood Vessel Wall	Blood Vessel Wall	Joeng et al., 2002	Blood Vessel Wall
Pharynx	Air	Air	None	Air
Pineal Body	Hypophysis	Hypophysis	Hypophysis	Thyroid gland
Placenta	Hand et al., 2010	N/A	Duncan et al., 1998 Wagner et al., 1980	Blood

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

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Testis	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Gabriel et al., 1996
Testis	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996
Thalamus	Brain (Grey Matter)	McIntosh et al., 2010	N/A	Brain (Grey Matter)
Thymus	Lymphnode and Fat	Lymphnode and Fat	Lymphnode and Fat	Gabriel et al., 1996
Thyroid Gland	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	Nakase et al., 2004	Gabriel et al., 1996
Tooth	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	None	Bone (Cortical)
Tooth (Dentine)	Duck, 1990 McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	None	Bone (Cortical)
Tooth (Enamel)	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	None	Bone (Cortical)
Trachea	Cartilage	Cartilage	Cartilage	Gabriel et al., 1996
Trachea Lumen	Air	Air	None	Air
Ureter\Urethra	Blood Vessel Wall	Blood Vessel Wall	John et al., 2002	Blood Vessel Wall
Urinary Bladder Wall	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	Water	McIntosh and Anderson, 2010	None	Peyman et al., 2012
Uterus	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Olsrud et al., 1998	N/A	Gabriel et al., 1996
Vagina	Large Intestine	Large Intestine	Wagner et al., 1980	Large Intestine
Vertebrae	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)
Water	Vaxasoftware	Engineering Toolbox Hyperphysics	None	Not in Database

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