Fundamentals of Heat Transfer

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Figure taken from: http://heatexchanger-design.com/2011/10/06/heat-exchangers-6/ Dated: 17-Jan-2012

Course contents mid term

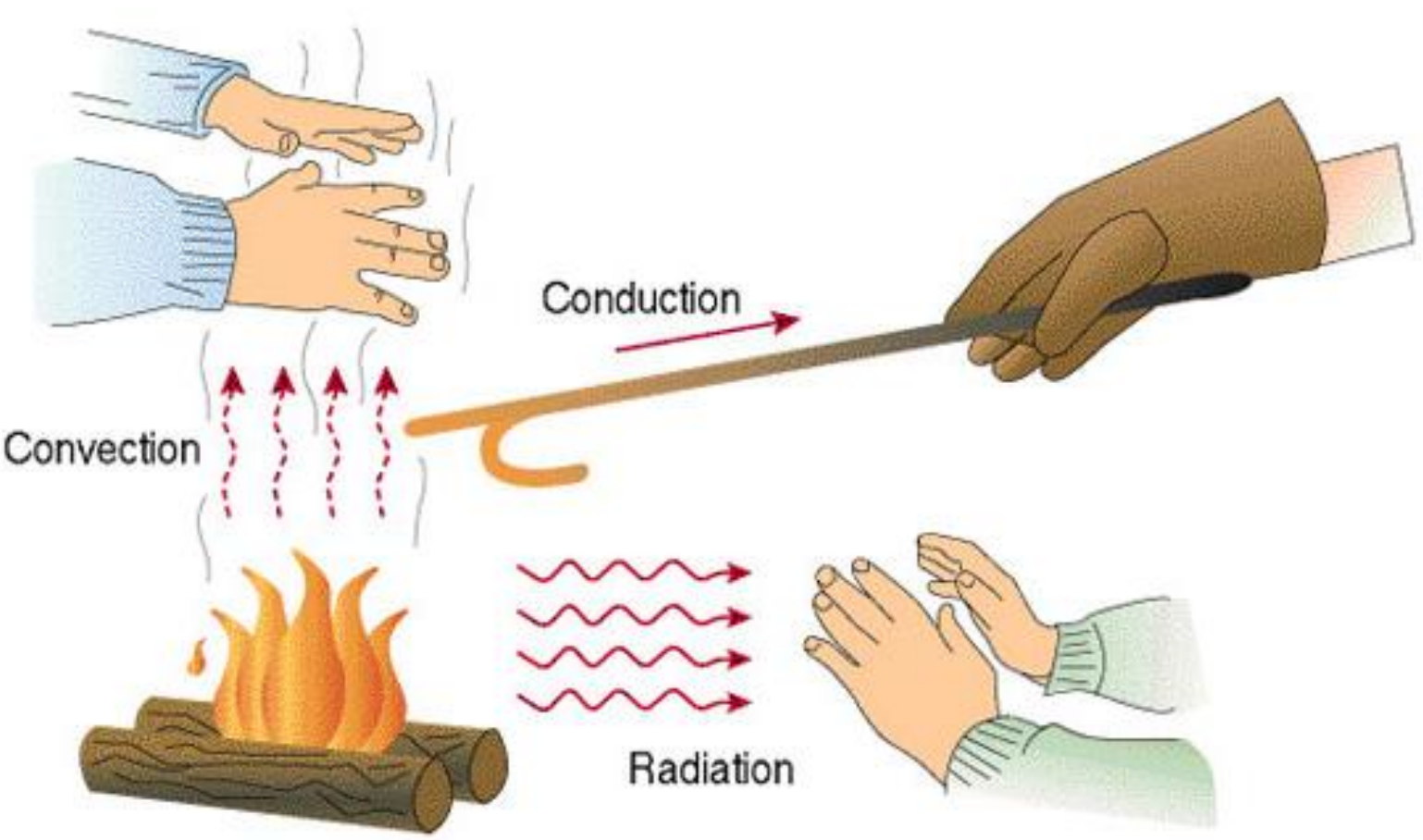
Introduction to transfer processes. Definition, applications, and various units of heat transfer. Modes of heat transfer: Conduction, convection, and radiation heat transfer. Fourier's law of heat conduction. Thermal conductivity of gasses, liquids, and solids. Units of thermal conductivity. Effect of temperature, pressure, and composition on thermal conductivity of materials. Estimation of thermal conductivity of gases, liquids, and solids. Introduction to steady-state heat transfer. Heat conduction through plane wall, hollow cylinder, and hollow sphere. Numerical problems related to heat conduction through plane wall, hollow cylinder, and hollow sphere. Thermal resistances in series: Composite plane wall, composite hollow cylinder, and composite hollow sphere. Numerical problems related to heat conduction through composite plane wall, composite hollow cylinder, and composite hollow sphere. Free and forced convection. Rate equation for convective heat transfer coefficient. Brief description of hydrodynamic boundary layer and heat transfer coefficient. Units of heat transfer coefficient. Individual and overall heat transfer coefficients: plane wall and hollow cylinder. Numerical problems regarding overall heat transfer coefficient. Determination of heat transfer coefficient. Description of various heat transfer correlations. Heat transfer in coiled and jacketed agitated vessels.

Modes of heat transfer

Unlike momentum transfer (fluid flow) and mass transfer, heat energy is transferred by three modes:

- Conduction
- Convection
- Radiation

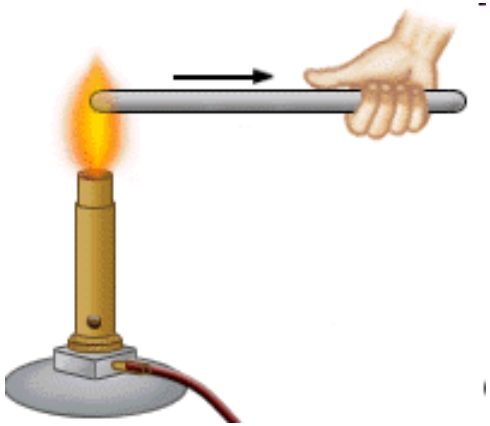
Modes of heat transfer

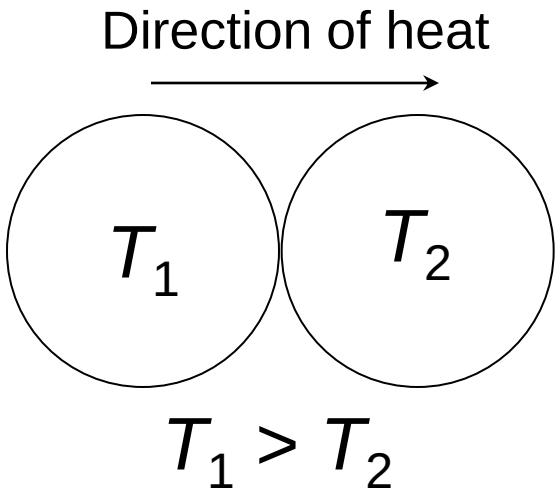


http://www.beodom.com/en/education/entries/principles-of-thermal-insulation-heat-transfer-via-conduction-convection-and-radiation

Conduction heat transfer

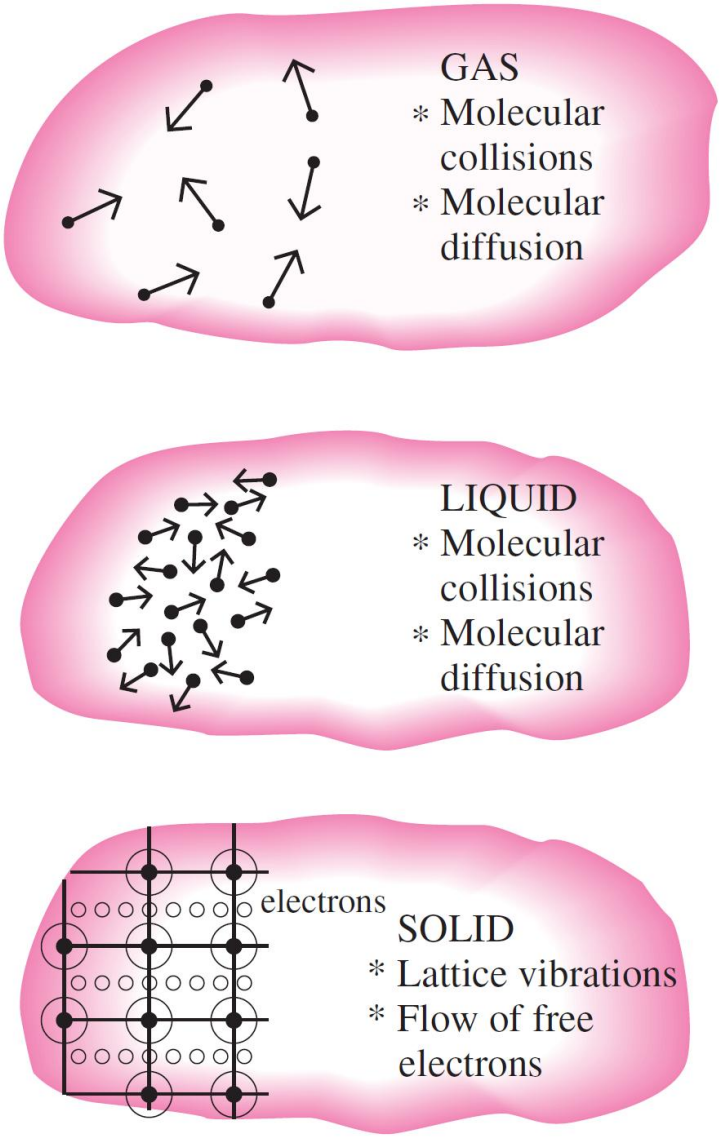
Heat conduction is applied to the mechanism of internal exchange from one body to another in contact, or from one part of a single body to another part by exchange of activity at molecular level. This exchange is the kinetic energy exchange by vibration of the atomic lattice, by movement of free electrons, or by molecular activity.





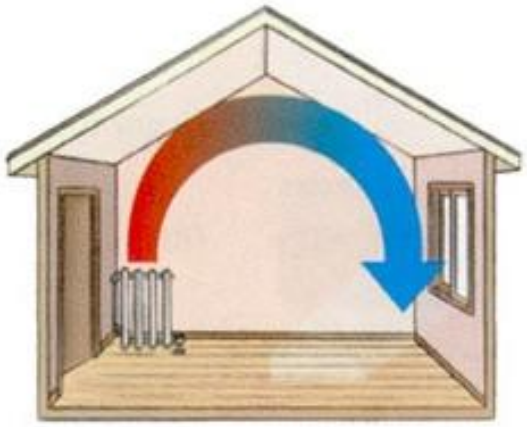
Left figure is taken from http://www.educationalelectronicsusa.com/p/heat-IV.htm

Mechanism of heat cnduction within various phases [3]



Convection heat transfer

Heat transfer by convection is due to fluid motion on a macroscopic scale, i.e., heat transfer mechanism occurs in a fluid by movement of the fluid and usually occurs through by mixing of one portion of the fluid with another portion due to gross movement of the mass of the fluid. The actual process of energy transfer from one fluid particle or molecule to another is still one of conduction, but energy may be transported from one point to the other by displacement of fluid itself. Convection is important in fluids.



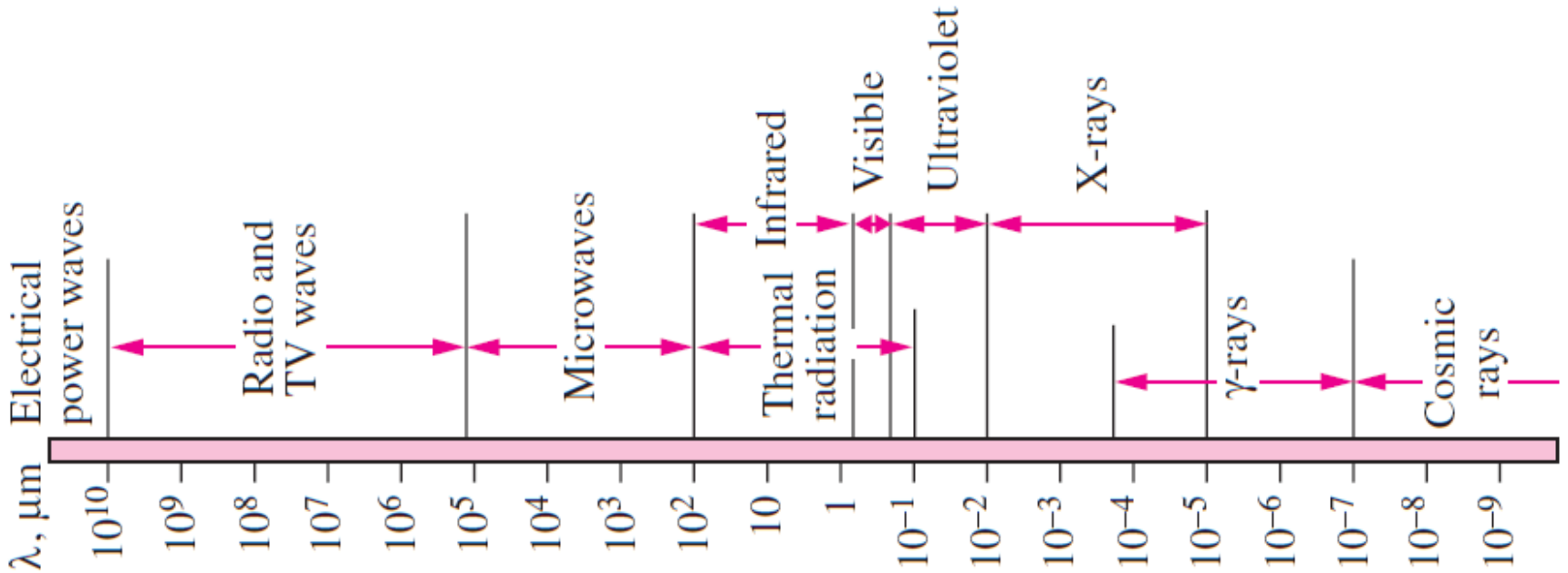
Convection heat transfer

In which of the following cases heat transfer will be higher in heating a fluid?

a) Conduction or b) Convection

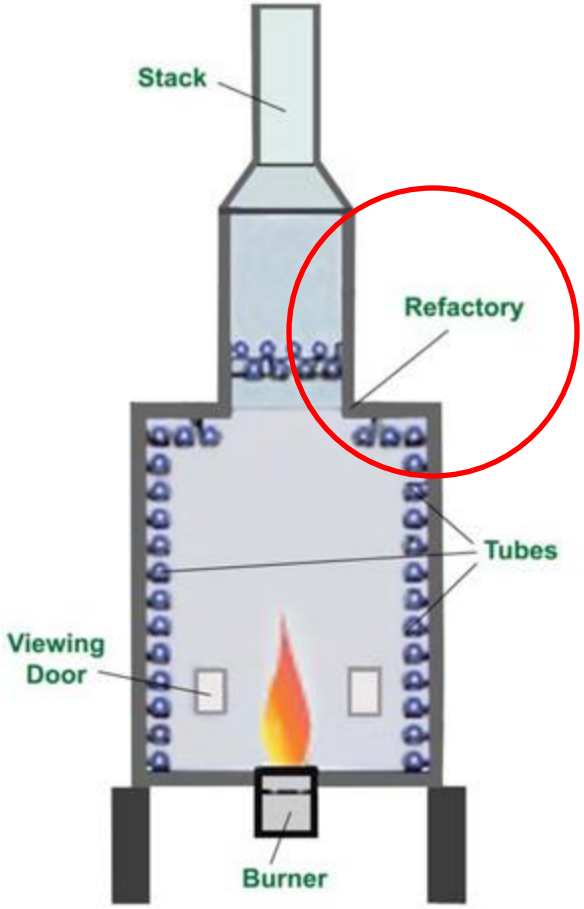
Radiation heat transfer

Radiation is unique as it does not require any physical medium for heat transfer. Energy transfer by radiation occurs by means of electromagnetic radiations.



Electromagnetic radiation spectrum [3]

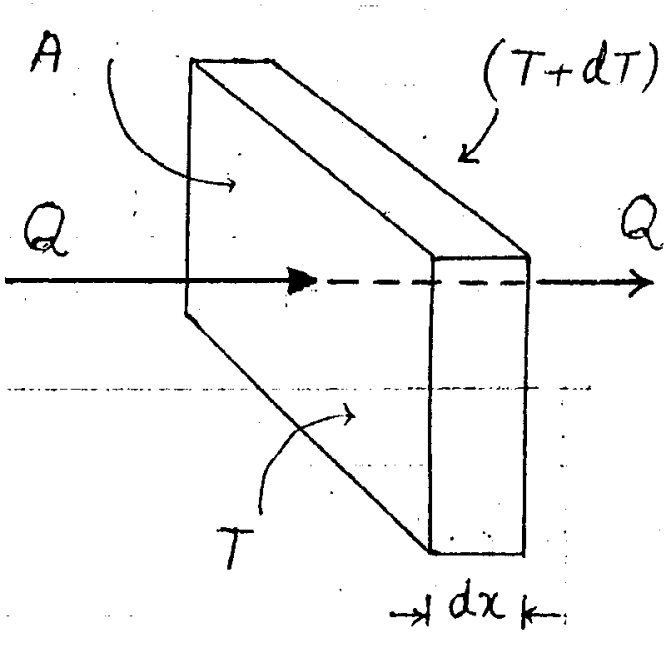
Steady-state conduction heat transfer



http://www.lenoxinst.com/Hydrocarbon-Processing.html Accessed on: 03-Jan-2014

Fourier's law of heat conduction

The rate of flow of heat through a single homogeneous solid is directly proportional to the area of the section at right angles to the direction of heat flow, and to the change of temperature with respect to the length of the path of the heat flow (temperature gradient).



Joseph Fourier

Fourier's law of heat conduction

$$q \propto A$$

$$q \propto \frac{dT}{dx}$$

$$q = -k \cdot A \cdot \frac{dT}{dx}$$

$$\frac{q}{A} = -k \cdot \frac{dT}{dx} \qquad (1)$$

$$heat\ flux \propto normal\ temperature\ gradient$$

Thermal conductivity

In Eq. 1, "*k*" is called Fourier's law proportionality factor and known as "thermal conductivity" of a material through which heat is flowing.

It is the quantitative measure of the heat conducting ability of a material.

Define thermal conductivity from Fourier's law of heat conduction (Eq. 1).

Thermal conductivity

SI units of thermal conductivity are

$J \cdot s^{-1} \cdot m^{-1} \cdot °C^{-1}$ or $J \cdot s^{-1} \cdot m^{-1} \cdot K^{-1}$

Or

$W \cdot m^{-1} \cdot °C^{-1}$ or $W \cdot m^{-1} \cdot K^{-1}$

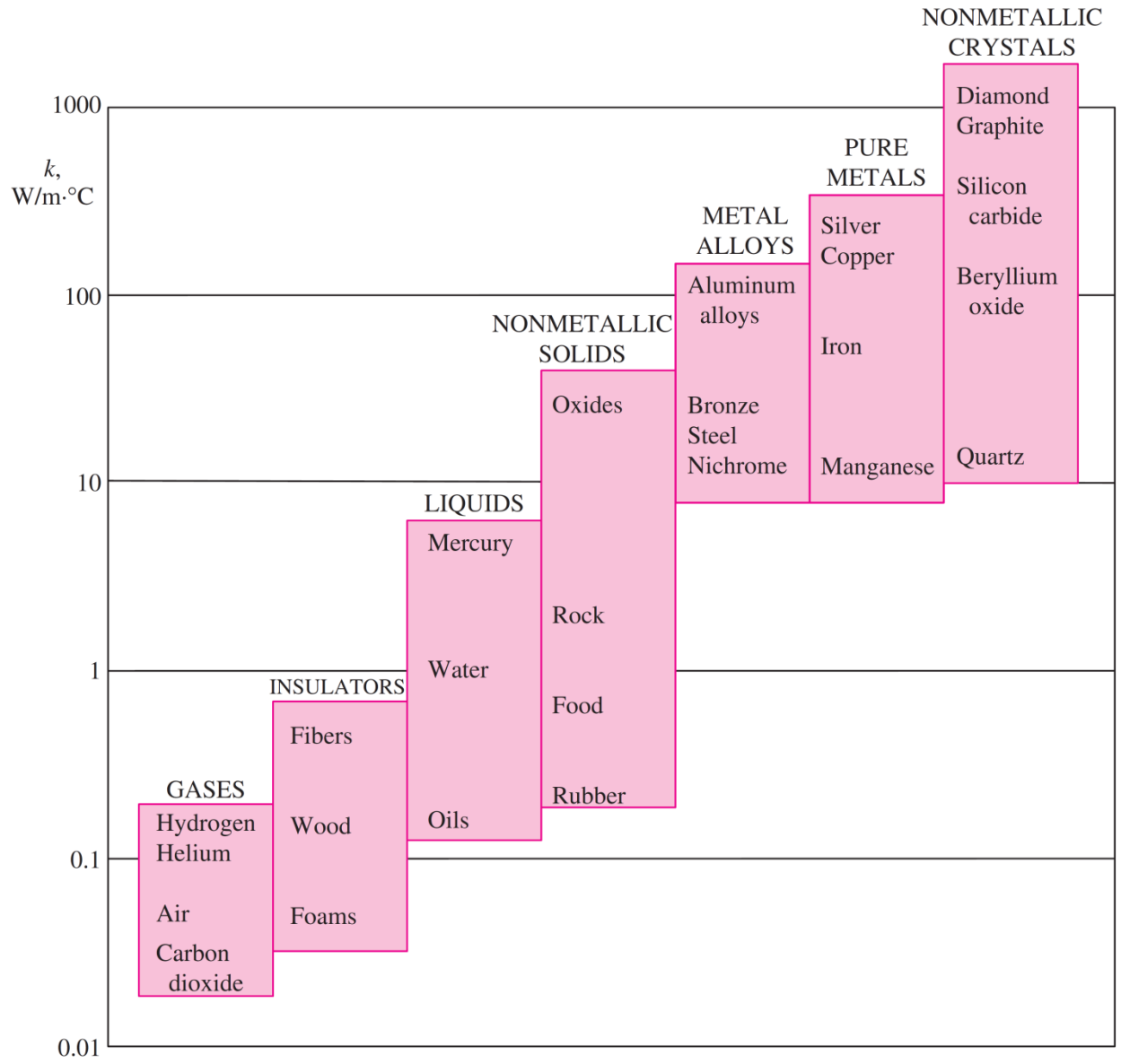
What will be the units in English system?

$1.0\ Btu \cdot h^{-1} \cdot ft^{-1} \cdot °F^{-1} = 1.73073\ W \cdot m^{-1} \cdot °C^{-1}$

Thermal conductivity of common materials at 0 °C [2]

Material	Thermal conductivity ($W \cdot m^{-1} \cdot °C^{-1}$)	Temperature (°C)	Reference
Air	0.0242	0	1
Water	0.569	0	1
Iron (pure)	73	0	2

Ranges of thermal conductivity at room temperature [3]



References

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