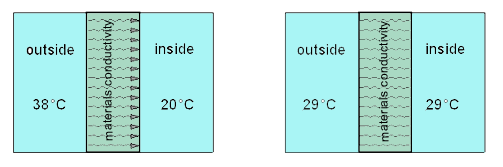
**General thermal requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| [Heat flow](https://www.boeingconsult.com/Environment/thermal-calculations-a.html#sec1) | [Thermal conductance](https://www.boeingconsult.com/Environment/thermal-calculations-a.html#sec2) | [Thermal conductivity](https://www.boeingconsult.com/Environment/thermal-calculations-a.html#sec3) | [Thermal resistance](https://www.boeingconsult.com/Environment/thermal-calculations-a.html#sec4) |

The First Law of Thermodynamics is the low of conservation of energy. The second law states that heat flows form hotter body to a cooler body. The easiest way to conserve energy would be to accept a lower temperature inside in winter and a higher temperature in summer. People should be encouraged to wear warmer clothes in winter to safe on heating costs. Cooling costs in summer could be reduce by accepting an inside temperature adjusted to the outside temperature. If we accept a temperature range from 22°C to 26°C related to the outside temperature the cooling cost would be much less.

**Conductivity and thermal resistance**

As show in Figure 1 heat will flow through a building material until equilibrium is reached (Law of Thermodynamics). The heat travels trough the material by conductivity. The thermal conductance (C) is measured in W/m²×°C.

  
Figure 1

[[top](https://www.boeingconsult.com/Environment/thermal-calculations-a.html#top)]

**Thermal conductance**

The thermal conductance is the time rate of heat flow through a material of a given thickness per unit temperature gradient across the material. Also known as Heat Transfer Coefficient.

|  |  |
| --- | --- |
|  | Consider a building material where the temperature difference between to parallel faces one metre apart is 1°C.  If the heat flows at a rate of 1 Watt per square metre through this one metre thickness, the material has a thermal conductivity of  **1 W/m²×°C**  **(1 Watt per metre thickness per 1°C)** (This is useful for comparing materials.) |

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**Thermal conductivity**

Very similar to, and often confused with, Conductance as described above. The difference to be noted is that Conductance involves area while Conductivity involves length.

For most building materials you will find standard figures that enables you to calculate an R value for a given thickness.

The thermal conductivity is also known as the k-value (or as SI unit )

Approximate k-values in W / m °C of the thermal conductivity's of some substances are shown in Table 1

                           Table 1\*

|  |  |  |  |
| --- | --- | --- | --- |
| Concrete | 1.440 | Plaster (cement) | 0.650 |
| Clay brick | 1.100 | Polystyrene | 0.036 |
| Glass | 0.700 | Polyurethane foam | 0.025 |
| Glass fibre (batts) | 0.042 | Softwood | 0.110 |
| Hardwood | 0.190 | Steel | 50.000 |
| Motionless dry air | 0.023 | Water | 0.600 |

(\*Be aware that some of the above figures can have a range  
and vary; depending on the source.)

The SI units for the figures in Table 1 are:

**watt / metre degree kelvin [W / m °K]**

It makes no difference whether we use degree celsius or degree kelvin, because the temperature difference between 1 °C is the same as 1 °K

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**Thermal resistance**

Thermal resistance (R) is the reciprocal of thermal conductance. It is a measure of the resistance to heat transmission across a material, or a structure.

The "R value" of a wall or an insulating material is its resistance to the flow of heat energy. The higher the R-value, the higher the energy efficiency. The R-value is the reciprocal of the U-value

|  |
| --- |
| & |

Thermal conductivity figures refer always to one metre thickness of a specific building material. To calculate the R-value of a particular material we must divide the thickness of the material by the k-value.

The thermal resistance (R) of single layer is calculated by dividing the layer thickness (s) by the k-value:



   s = thickness in metres  
   k = thermal conductivity

The total thermal resistance (R) of a given building element can be calculated by adding each single element (material) together as shown in the formula below:

*Rtotal= fo*

fo = external surface resistance

fi = internal surface resistance  
k = conductivity of material  
s = material thickness in metres

The fo and fi in the above equation stand for external and internal surface resistance. This air film accounts for the effects of the convective and radiative components of the heat exchange at the surface. The inside air film layer (fi) is considered to be still air and the outside layer (fo)is considered to be moving air. Typical normal figures are:

fo = 0.4 to 0.6  
    fi = 0.12 to 0.15

Please note that the American publication give R-values in imperial units. To convert the American units in metric unit you must multiply them by 0.176 or divide our R-values by 0.176 to compare them with the American figures. (e.g. American R 8 is R 1.4 in metric units)

An example calculation of the R-value is outlined below for:

|  |  |
| --- | --- |
| a) Wall 1 | 200 mm concrete wall |
| b) Wall 2 | 200 mm concrete wall  with a 100 mm polystyrene insulation. |

Using the above formula and the figure from Table 1 the R-value is:

|  |  |
| --- | --- |
| a) | b) |

Remember that the unit for the material thickness must be in metre.

The figure below shows the relevance of the R-values graphically.

|  |
| --- |
| (a)                                               (b) |

Figure 3

The diagrams above are vertical slices through exterior walls. Figure 3 (b) shows how the position of the external insulation helps to keep the wall structure and interior surfaces warm. The range of the outdoor air temperature in (a) and (b) is 45°C (-5°C Winter and +40°C Summer) and the indoor air temperature is kept constant at 20°C (Summer and Winter). The thick solid diagonal lines show the temperature within the wall at various points. Note the warmth of the wall structure in (b); it's the external insulation at work.

The inside surface of the wall is nearer to the temperature of the inside air. Thus, the building's occupants do not gain or lose heat as readily by being near surfaces that are hotter or colder than the indoor air. (Keeping the wall warm also has the advantage of keeping water pipes in the wall from freezing in the winter.)

Figure 3 also indicates that with an external yearly temperature range of 45° (-5°C Winter and 40°C Summer) the thermal stress in the material (a) is extreme compared to (b) and of course for (a) much more energy is needed to maintain a comfortable internal surface temperature throughout the year.

[[top]](https://www.boeingconsult.com/Environment/thermal-calculations-a.html#top)