



PASSIVE DESIGN. THERMAL PROPERTIES

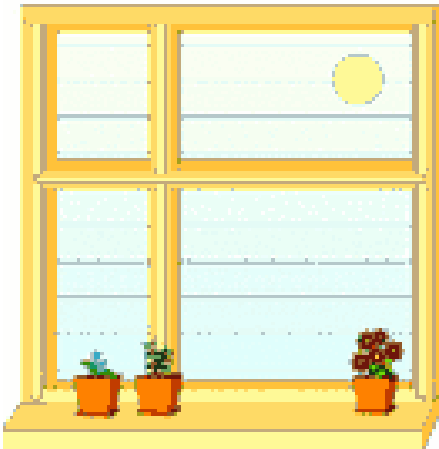
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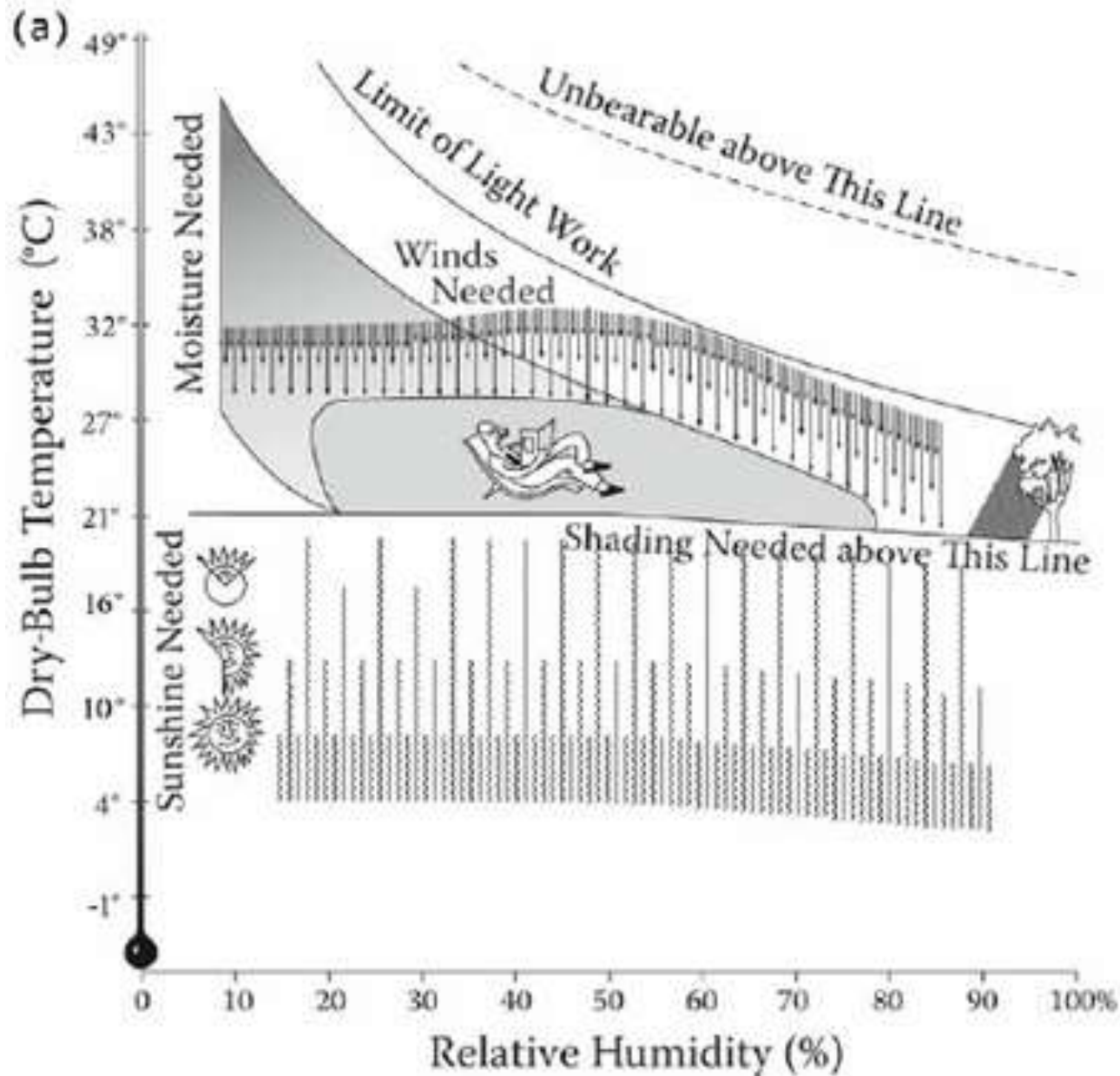


Thermal comfort



- Physical and mental activity
- Metabolism
- Individual natural insulation
- Warm clothing
- Air temperature
- Radiation temperature
- Air movement
- Air humidity





Adapted from
Olgyay's
bioclimatic
chart



Mechanisms of heat transfer

- Radiation
- Convection
- Induction



Heat Exchange from one body to another



Fluid movement or inside the same element



Electron movement by mechanical vibration



Thermal properties

Heat transfer

- Thermal conductivity
- Resistance
- Transmittance

Heat storage

- Specific heat
- Thermal mass



Thermal conductivity

Capacity of a material to conduct heat through it

The higher conductivity, the higher heat transfer

Units in **W/(mK)**



Thermal conductivity (λ) in W/(mK)

Water	0.58	Iron	80.2
Air	0.02	Steel	47-58
Timber	0.13	Aluminium	209
Cork	0.04-0.30	Bronze	116-186
Glass fibre	0.03-0.07	Zinc	106-140
Polyurethane	0.018-0.025	Copper	372-385
Brick	0.80	Gold	308
Firebrick	0.47-1.05	Silver	406-418
Glass	0.6-1.0	Lead	35.0
Asbestos	0.04	Lithium	301



Thermal Resistance (R-value)

Capacity of materials to prevent heat from being conducted through it

It is measured through thermal resistance ($\text{m}^2\text{K/W}$)

It is the inverse to thermal conductivity

The R-value of a multilayer wall is the summation of all thermal resistances



Thermal transmittance (U-value)

Rate of heat transfer through one square metre of a structure divided by the difference in temperature across the structure

Expressed in **W/m²K**



How to calculate the U-value

$$R_i = \frac{\text{thickness (m)}}{\lambda}$$

$$R = \sum_{i=0}^{i=n} R_i$$

$$U = \frac{1}{R}$$

U = U-value (transmittance)

R = R-value (thermal resistance)

i = layer

n = total number of layers

λ = thermal conductivity



Example

Calculate the thermal transmittance of a wall formed by the following layers:

Plastering. 20mm. $\lambda=0.50\text{W/mK}$

Brick Masonry. 500mm. $\lambda=1.2\text{W/mK}$

Mortar render. 25mm. $\lambda=0.80\text{W/mK}$

$$R_{\text{plastering}} = \frac{0.020}{0.50} = 0.0400$$

$$R_{\text{masonry}} = \frac{0.500}{1.20} = 0.4167$$

$$R_{\text{mortar}} = \frac{0.025}{0.80} = 0.0313$$

$$R = 0.0400 + 0.4167 + 0.0313 = 0.4880$$

$$U = \frac{1}{R} = 2.0492 \text{ W/m}^2\text{K}$$



Thermal transmittance (U-value)

L1A, new dwellings, 2013 edition

Roof	0.2 W/(m ² K)
Wall	0.3 W/(m ² K)
Floor	0.25 W/(m ² K)
Party wall	0.2 W/(m ² K)
Swimming pool basin	0.25 W/(m ² K)
Windows, roof windows, glazed roof-lights, curtain walling and pedestrian doors	2.0 W/(m ² K)
Air permeability	10.0 m ³ /(h.m ²) at 50 Pa



Thermal transmittance (U-value)

L2A, new buildings other than dwellings, 2013 edition

Roof	0.25 W/(m ² K)
Wall	0.35 W/(m ² K)
Floor	0.25 W/(m ² K)
Swimming pool basin	0.25 W/(m ² K)
Windows, roof windows, roof-lights, curtain walling and pedestrian doors	2.2 W/(m ² K)
Vehicle access and similar large doors	1.5 W/(m ² K)
High-usage entrance doors	3.5 W/(m ² K)
Roof ventilators (inc. smoke vents)	3.5 W/(m ² K)
Air permeability	10.0 m ³ /(h.m ²) at 50 Pa



Thermal transmittance (U-value)

L1B and L2B, existing dwellings and existing buildings other than dwellings, 2010 editions

	New thermal elements	Retained thermal elements
Wall	0.28 W/(m ² K)	
Pitched roof – insulation at ceiling level	0.16 W/(m ² K)	0.16 W/(m ² K)
Pitched roof – insulation at rafter level	0.18 W/(m ² K)	0.18 W/(m ² K)
Flat roof or roof with integral insulation	0.18 W/(m ² K)	0.18 W/(m ² K)
Floors	0.22 W/(m ² K)	0.25 W/(m ² K)
Swimming Pool basin	0.25 W/(m ² K)	
Wall – cavity insulation		0.55 W/(m ² K)
Wall – external or internal insulation		0.30 W/(m ² K)



The specification for the notional domestic building referred to in Part L1A has considerably lower values, for example:

- External wall: $0.18 \text{ W/m}^2\text{K}$.
- Floor: $0.13 \text{ W/m}^2\text{K}$.
- Roofs: $0.13 \text{ W/m}^2\text{K}$.
- Windows, roof windows, glazed rooflights and glazed doors: $1.4 \text{ W/m}^2\text{K}$.



RESISTANCE OF AIR LAYERS (BRE 443)

Airspace which thickness is less than one tenth of width or height

Unventilated airspaces

- Normal (high) emissivity: $0.18 \text{ m}^2\text{K/W}$
- Low emissivity:
 - Heat flow horizontal (wall applications): $0.44 \text{ m}^2\text{K/W}$
 - Heat flow upwards (roof applications): $0.34 \text{ m}^2\text{K/W}$
 - Heat flow downwards (floor applications): $0.50 \text{ m}^2\text{K/W}$

Ventilated airspaces

- High- emissivity surface
 - Heat flow horizontal (wall applications): 0.13
 - Heat flow upwards (roof applications): 0.10
- Low emissivity surface
 - Heat flow horizontal (wall applications): 0.29
 - Heat flow upwards (roof applications): 0.17



Solve exercises in class

Insulation

Materials, Classification and
Characteristics

Characteristics

- Thermal Conductivity (λ)
 - The ease with which heat can move through a material
- Thermal Resistance (R)
 - Connects the conductivity with the depth of the material
 - Resistance per unit area ($\text{m}^2\text{K/W}$)
 - Higher resistance = better insulator
- Specific Heat Capacity
 - The amount of heat need to raise the temperature of 1kg of material by 1K (or 1°C)
 - Higher the capacity = better insulator

Characteristics

- Density
 - The mass per unit volume in kg/m^3
- Thermal Diffusivity
 - The ability of a material to conduct thermal energy relative to its ability to store thermal energy
 - Low thermal diffusivity = better insulator
 - Thermal diffusivity (mm^2/s) = Thermal conductivity / Density x Specific Heat Capacity
- Vapour Permeability
 - The extent to which a material allows the passage of water through it
 - Usually characterised as Vapour Permeable or Non-Vapour Permeable

Wood Fibre



Thermal Conductivity	0.038
Thermal Resistance	2.5-2.6
Specific Heat Capacity	2100
Density	50-160
Thermal Diffusivity	n/a
Embodied Energy	n/a
Vapour Permeable	Yes

Cellulose



Thermal Conductivity	0.035-0.040
Thermal Resistance	2.632
Specific Heat Capacity	2020
Density	27-65
Thermal Diffusivity	n/a
Embodied Energy	0.45
Vapour Permeable	Yes

Wool



Thermal Conductivity	0.038
Thermal Resistance	2.63
Specific Heat Capacity	1800
Density	23
Thermal Diffusivity	n/a
Embodied Energy	6
Vapour Permeable	Yes

Hemp



Thermal Conductivity	0.039-0.040
Thermal Resistance	2.5
Specific Heat Capacity	2300
Density	25-38
Thermal Diffusivity	n/a
Embodied Energy	10
Vapour Permeable	Yes

Hempcrete



Thermal Conductivity	0.06
Thermal Resistance	1.429
Specific Heat Capacity	1500-1700
Density	275
Thermal Diffusivity	1.5×10^{-7}
Embodied Energy	n/a
Vapour Permeable	Yes

Cellular Glass



Thermal Conductivity	0.041
Thermal Resistance	n/a
Specific Heat Capacity	1000
Density	115
Thermal Diffusivity	4.2×10^{-7}
Embodied Energy	n/a
Vapour Permeable	No

Straw



Thermal Conductivity	0.08
Thermal Resistance	4.37 at 350mm
Specific Heat Capacity	Unavailable
Density	110-130
Thermal Diffusivity	Unavailable
Embodied Energy	0.91
Vapour Permeable	Yes

Glass Mineral Wool



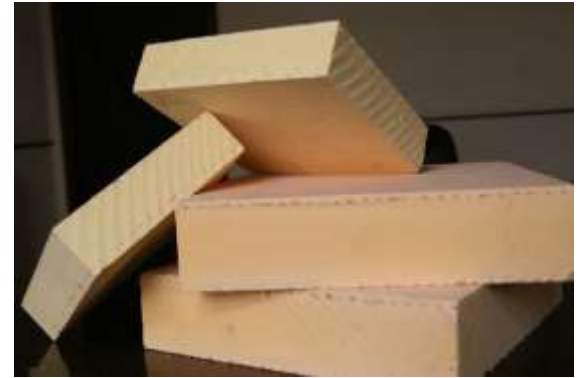
Thermal Conductivity	0.035
Thermal Resistance	2.85
Specific Heat Capacity	1030
Density	c. 20
Thermal Diffusivity	0.0000016
Embodied Energy	26
Vapour Permeable	Yes

Rock Mineral Wool



Thermal Conductivity	0.032-0.044
Thermal Resistance	2.7-2.85
Specific Heat Capacity	n/a
Density	n/a
Thermal Diffusivity	n/a
Embodied Energy	n/a
Vapour Permeable	Yes

Phenolic Foam



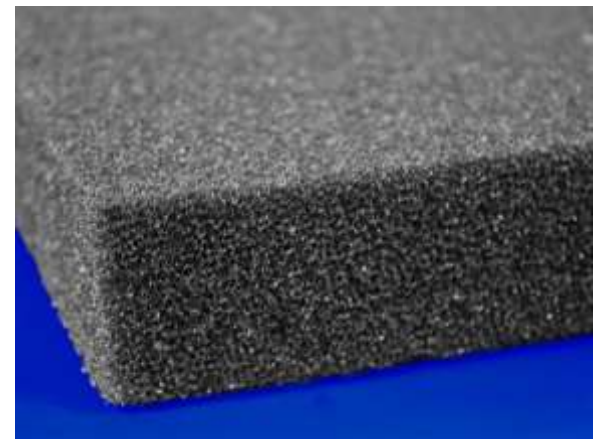
Thermal Conductivity	0.020
Thermal Resistance	5.00
Specific Heat Capacity	n/a
Density	35
Thermal Diffusivity	n/a
Embodied Energy	n/a
Vapour Permeable	No

Polyurethane Foam



Thermal Conductivity	0.023-0.026
Thermal Resistance	4.50
Specific Heat Capacity	n/a
Density	30-40
Thermal Diffusivity	n/a
Embodied Energy	101
Vapour Permeable	No

Low Density Polyurethane Foam



Thermal Conductivity	0.039
Thermal Resistance	n/a
Specific Heat Capacity	n/a
Density	7.5-8.3
Thermal Diffusivity	n/a
Embodied Energy	n/a
Vapour Permeable	No

Expanded Polystyrene



Thermal Conductivity	0.034-0.038
Thermal Resistance	3.52
Specific Heat Capacity	1300
Density	15-30
Thermal Diffusivity	Unavailable
Embodied Energy	88.60
Vapour Permeable	No

Extruded Polystyrene



Thermal Conductivity	0.033-0.035
Thermal Resistance	3
Specific Heat Capacity	n/a
Density	20-40
Thermal Diffusivity	n/a
Embodied Energy	88.6
Vapour Permeable	No

Aerogel



Thermal Conductivity	0.014
Thermal Resistance	3.8 for 50mm
Specific Heat Capacity	1000
Density	150
Thermal Diffusivity	Unavailable
Embodied Energy	5.4kg / CO ₂ per m ²
Vapour Permeable	No