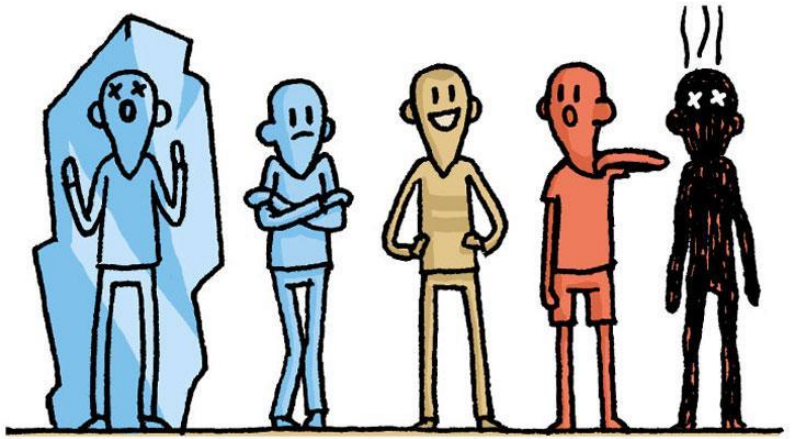
1. Thermal Comfort – requirements

What is thermal comfort?

- Thermal comfort is a human's perception of comfort with respect to objective measures, such as temperature, humidity, and air velocity.

Problem:

- Poor indoor air quality in living spaces can have a negative affect on human health and personal performance.



What is indoor air quality?

- Indoor air quality (IAQ) is defined by the concentrations of various pollutants.

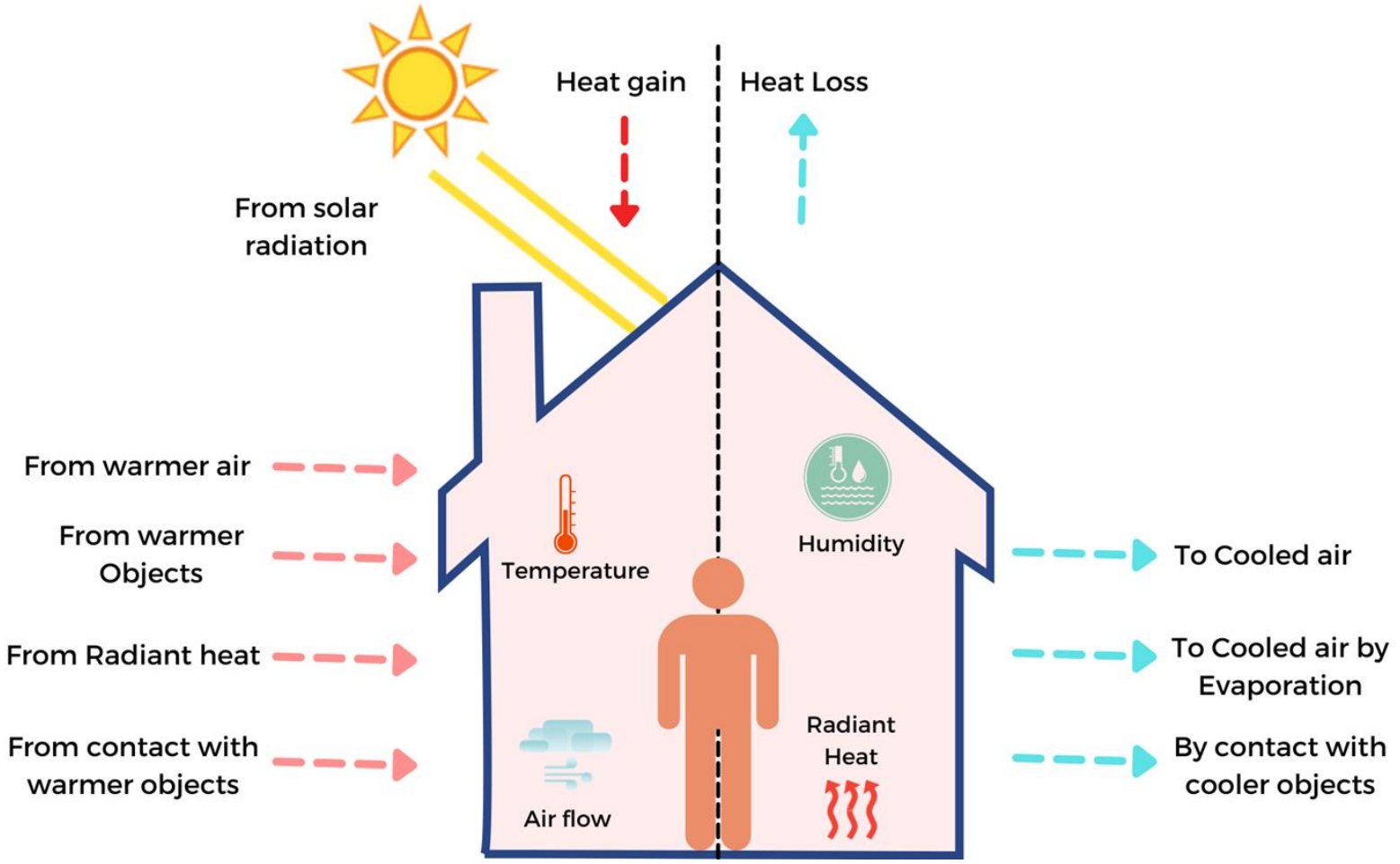
Overall thermal comfort

The term thermal comfort is understood as a state of mind that reflects a person's satisfaction with the thermal environment and that is based on a subjective assessment.

it depends on sensory perception

- psychological influences
- experience with the thermal state of the environment

Thermal



Source: https://www.linkedin.com/pulse/building-thermal-comfort-analysis-ecologikol?trk=organization-update-content_share-article

Requirements

European standard EN 16 798-1 (with national translation STN EN 16 798-1) "Input parameters of the indoor environment for designing and evaluating the energy efficiency of buildings - addressing indoor air quality, thermal environment, lighting and acoustics" specifies how design criteria can be established and is used for sizing systems

The purpose of the international standard EN ISO 7730 "Moderate thermal environment - Determination of PMV and PPD indices and specification of conditions for a thermal environment" is to present a method for predicting the thermal sensation and degree of discomfort (thermal dissatisfaction) of people exposed to a moderate thermal environment and to specify acceptable environmental conditions for comfort.

Requirements

European Technical Report CEN CR 1752 "Ventilation of buildings - Design criteria for indoor environments" covers criteria for indoor air quality, ventilation, thermal comfort and noise. Critical issues such as adaptation, effect of increased air velocity, humidity, type of indoor pollution sources, etc. are still being debated, but in general these standards can be used worldwide.

An equation in EN ISO 7730 calculates the PMV index based on the six factors clothing, activity, air and mean radiant temperature, air velocity and humidity. Even if a PMV value of 0 is obtained, there will still be at least 5% of the occupants who will be dissatisfied with the thermal environment.

Table 1: Acceptable thermal environment for general comfort (ASHRAE Handbook, EN ISO 7730)

PPD	PMV
< 10	- 0.5 < PMV < + 0.5

Table 2: Example design criteria for spaces in various types of building (EN ISO 7730)

Type of building/space	Activity [W/m²]	Category	Operative temperature [°C]	
			Summer (cooling season)	Winter (heating season)
Single office Landscape office Conference room Auditorium Cafeteria/restaurant Classroom	70	A	24,5 ± 1,0	22,0 ± 1,0
		B	24,5 ± 1,5	22,0 ± 2,0
		C	24,5 ± 2,5	22,0 ± 3,0

According to standard **STN EN 16798-1** are four categories indicated by numbers from I to IV. The categories I, II and III correspond to categories A, B and C in tables above. The category IV accounts for short deviations (for example exceeding the noise level when opening window for a short period of time, etc.) This category can be accepted only certain period of time.

Table 3: Description of applicability of individual categories in STN EN 16798-1

Category	Explanation
I	High level of expectations
II	Average level of expectations
III	Permissible level of expectations
IV	Low level of expectations

Recommended values for the acceptable range of the indoor temperature for heating and cooling are based on a range for the PMV-index.

Type of building/space	**Category**	**Heating temperature range, [° C] Clothing ~ 1.0 duty**	**Cooling temperature range, [° C] Clothing ~ 0.5 duty**
Apartment buildings: living rooms (bedrooms, kitchens) sedentary activities 1.2 met	I	21 – 25	23,5 – 25,5
	II	20 – 25	23 – 26
	III	18 – 25	22 – 27
	IV	17 – 25	21 – 28
Apartment buildings: other premises (halls, warehouses) standing / walking 1.5 met	I	18 – 25	
	II	16 – 25	
	III	14 – 25	
Offices and spaces with simple activity, open layout offices, lecture halls, cafes, classrooms, restaurants (sedentary activities 1.2 met)	I	21 – 23	23,5 – 25,5
	II	20 – 24	23 – 26
	III	19 – 25	22 – 27
	IV	17 - 25	21 - 28

Thermal resistance of clothing

Clothing, through its insulative properties, is an important modifier of body heat loss and comfort. Clothing unit represents the thermal resistance of the clothing (1 clothing unit = 1 clo = 0,155 m2K/W)

Clothing worn by people indoors is modified to a great extent by the season and outdoor weather conditions. During the summer months, typical clothing in commercial establishments consist of lightweight dresses, lightweight trousers, short- or long-sleeved shirts and blouses, and occasionally a suit jacket or sweater. During the winter season, people wear garments constructed of thicker, heavier (i.e., warmer) fabrics and often add more garment layers to an ensemble.

Thermal resistance of clothing

Table 5: Heating/cooling temperatures for office spaces (Standard EN 16 798-1)

Type of building or space	Category	Temperature range for heating, [°C] Clothing~ 1,0 clo	Temperature range for cooling, [°C] Clothing ~ 0,5 clo
Offices and spaces with similary activity (single offices, opan plan offices, conference rooms, auditorium, cafeteria, restaurants, class rooms) Sedentary activity ~ 1,2 met	I	21 – 23	**23,5 – 25,5**
	II	20 – 24	**23 – 26**
	III	19 – 25	**22 – 27**
	IV	**17 - 25**	**21 - 28**

Metabolic rate

Humans produce heat from approximately 80 to 1000 W depending on the activity level. For sedentary activity, as is usually used by administrative buildings, value of metabolic rate is 1.2 met = 126 W (ISO 7730).

Activity	met	W/m2
Reclining	0,8	46,6
Seated and quiet	1,0	58,2
Sedentary activity (ofice, dwelling, lab, school)	1,2	69,8
Standing, relaxed	1,2	69,8
Light activity, standing (shopping, lab, light industry)	1,6	93,1
Medium activity, standing (shop assistant, domestic work, machine work)	2,0	114,4
High activity (heavy machine work, garage work, if sustained)*	3,0	174,6
*Typically, rest breaks (scheduled or hidden) or other operational factors (get parts, move products, et.) combine to limit most individual work to a time-weighted average level of about 2 met.		

Operative temperature

Two parameters that the operative temperature describes – air temperature and mean radiant temperature.

Because of the seasonal clothing habits of building occupants, the temperature range for comfort in summer is higher than in winter.

Compared to a convective heating/cooling system a radiant surface heating system can achieve the same level of operative temperature at a lower air temperature and a surface cooling system at a higher air temperature.

Season	**Description of typical clothing**	**L_{cl} (clo)**	**Optimum operative temperature**	**Operative temperature range (10% dissatisfaction**
Winter (°C)	Heavy slacks long-sleeve shirt and sweater	0,9	22 °C	22-23,5 °C
Summer (°C)	Light slacks and short-sleeve shirt	0,5	24,5 °C	23-26 °C
	minimal	0,05	27 °C	26-29 °C

Operative temperature

- An important factor in radiant heating is the angle between the heating surface / source and the occupant.
- This factor depends on the distance between man and the surface and on the surface area.
- The center of the seated person is only 0.6 m away floor, while the distance from the ceiling is 1.8 to 2.1 m.
- Therefore, the floor usually has the highest angle factor of all surfaces (walls, ceiling, windows, etc.) to the occupants

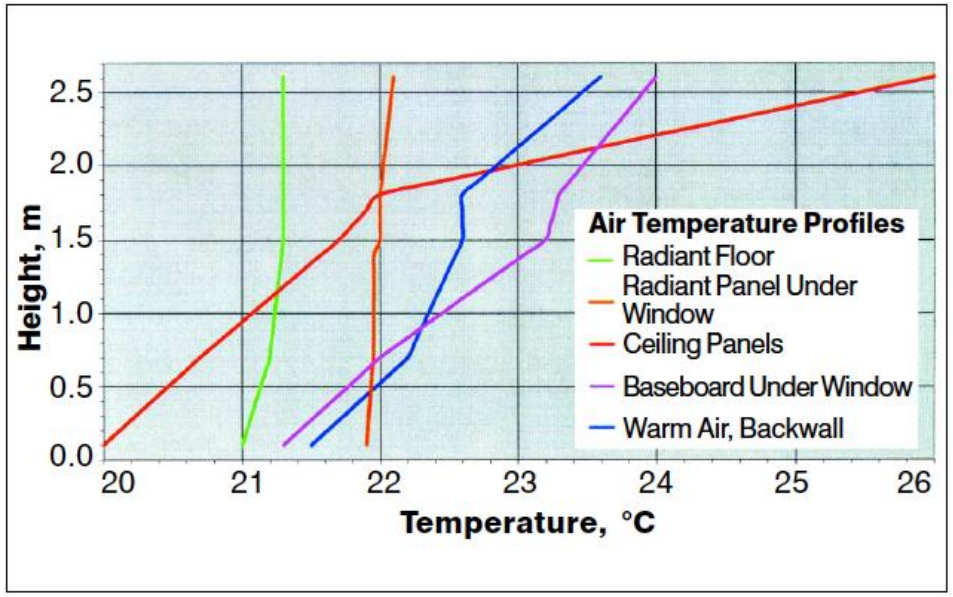


Figure 3: Vertical air temperature differences measured in a test space for different heating systems. Heat flux was 50 W/m^2 (Olesen, 2002).