MŰEGYETEM 1782

Comfort in Buildings

Thermal Comfort 1

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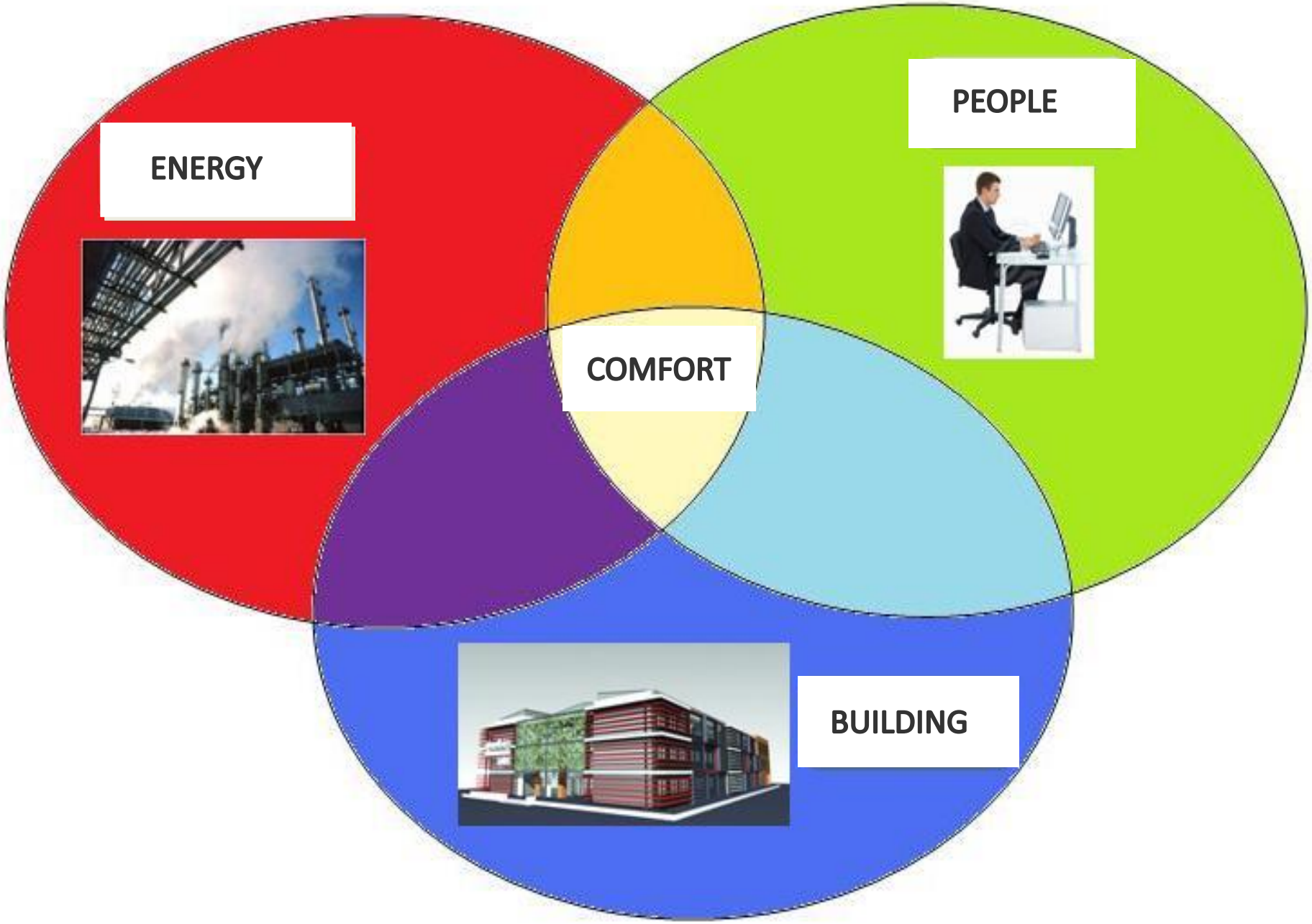
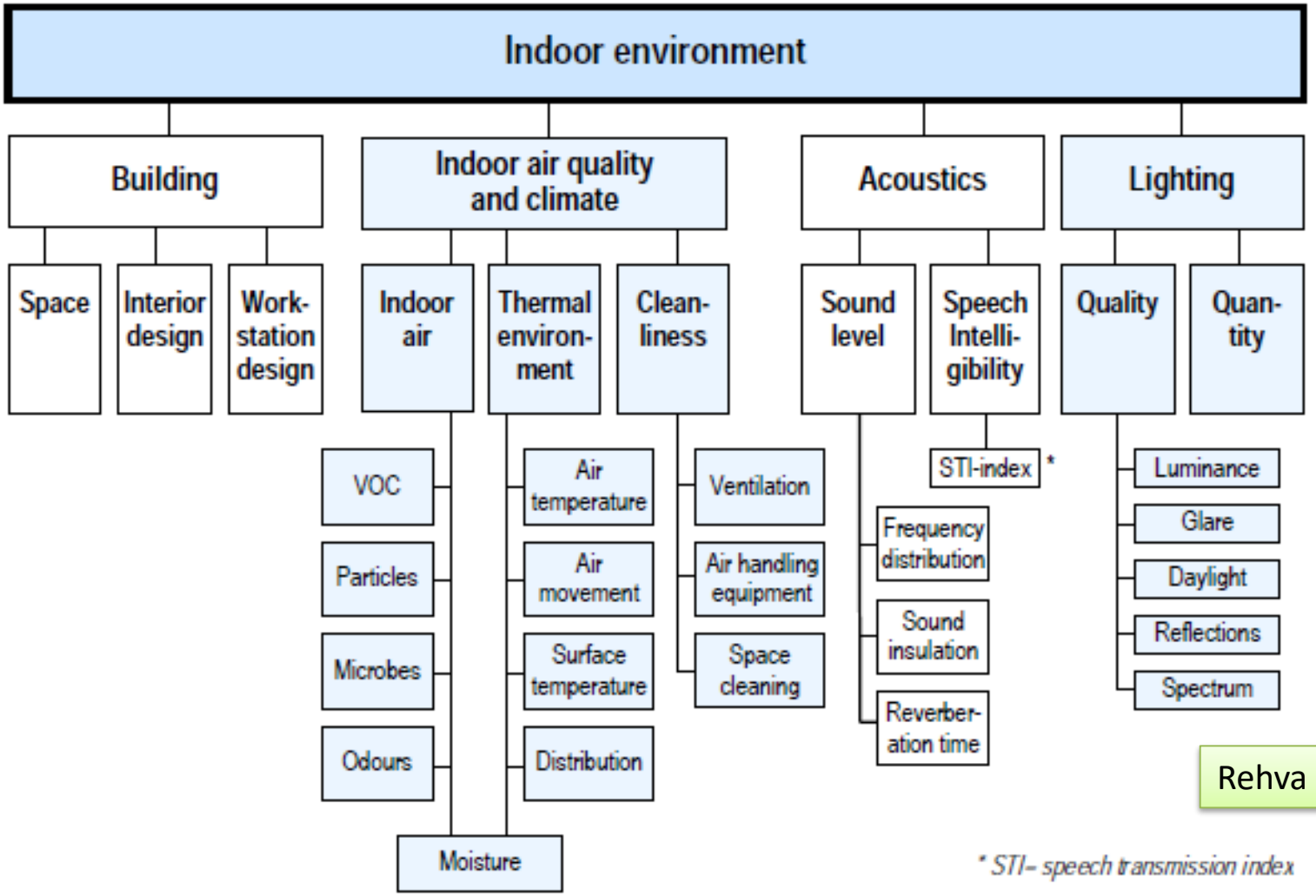
PROF / TRAC

Open Training and Qualification Platform on NZEB construction and renovation


ENERGY
PEOPLE
COMFORT
BUILDING

Indoor environment



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* STI– speech transmission index

Thermal discomfort

Within thermal discomfort may be considered complaints about:

- high temperatures;
- low temperatures;
- varying temperatures;
- draughts;
- radiation;
- hot or cold feet (floors).

In the short term, the thermal climate may have health effects as a consequence. Examples of health problems which may be related to this are:

- Headache (for example associated to low temperatures and high humidities (Bianchi et al, 2003))

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Visual discomfort

Visual discomfort may reveal itself in the following complaints:

- Too little daylight or artificial light;
- Dazzling daylight or artificial light;
- Inadequate visibility.

Poor lighting may also contribute for example to:

- Eye irritations;
- Neck and shoulder problems;
- Fatigue.

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Indoor air quality - discomfort

Poor indoor air quality may also affect health in the short term. Examples of short-term effects are:


Inflamed or irritated conjunctiva

- Eye irritation / red eyes;
- Complaints about dry throat / throat irritation;
- Blocked or running nose;
- Headache;
- Unusual fatigue (particularly at the end of the day);
- Dizziness.

Serious health problems in the short and medium term are:

- Incidence of infections, such as flu or colds;
- Asthma attacks and sensitisation of persons with a genetic tendency to asthma and allergens;
- Infection with Legionella bacteria (Legionnaire's disease) as a result of exposure to aerosols (tiny water droplets) infected with Legionella bacteria in the air, e.g. in showers in gyms;
- Carbon monoxide poisoning (symptoms are e.g. persistent headache and drowsiness). This happens quite seldom in educational buildings.

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Acoustic discomfort

Poor acoustics in rooms and noise from other rooms, from building services or from outside (traffic, playground) may lead to noise nuisance.

Noise nuisance may lead to:

- Reduction in concentration;
- Reduction in speech intelligibility;
- Voice problems.

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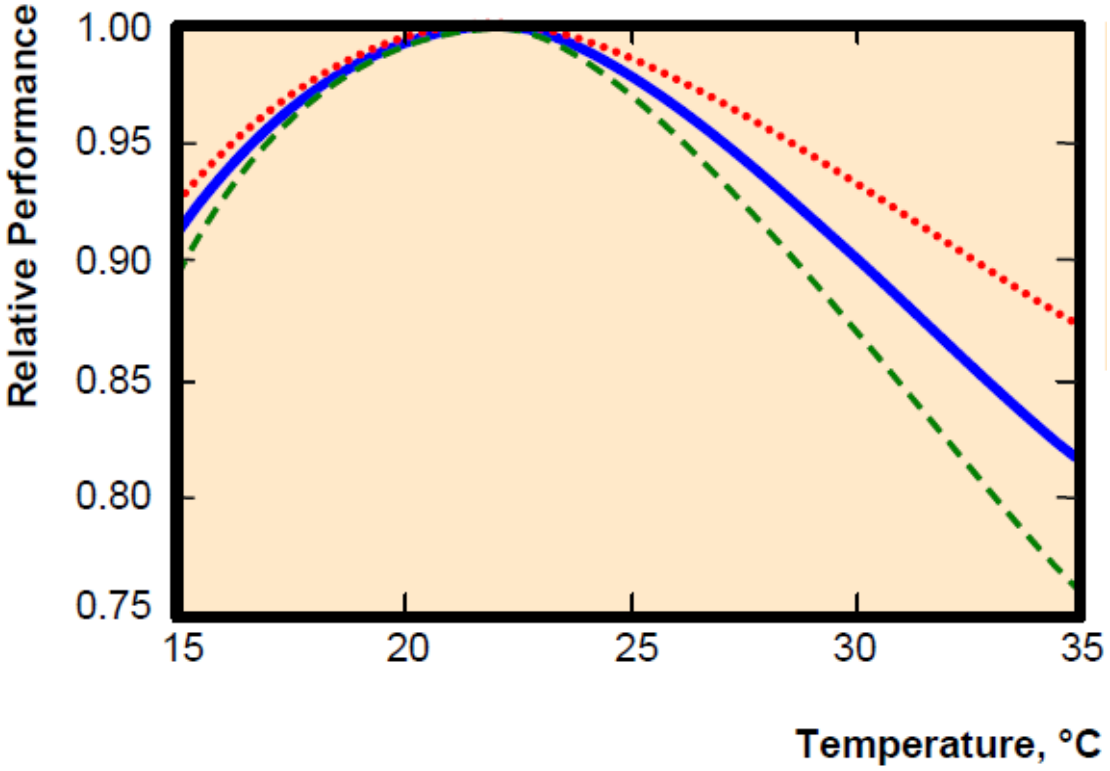
http://vancouver.ca/ctyclerk/cclerk/970513/citynoisereport/

Temperature and performance



Unweighted

Weighted by sample size and outcome relevance

Weighted by sample size

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Indoor environmental factors

- **Thermal comfort or indoor climate**
  - Temperature, humidity, air velocity
- **Visual or lighting quality**
  - View, illuminance, luminance ratios, reflection,…
- **Indoor air quality**
  - odours, indoor air pollution, fresh air supply,…
- **Acoustical quality**
  - Outside and indoor noise and vibrations

IEQ – criteria for classification

- Standard EN 15251

Indoor environmental input parameters for design and assessment of energy performance of buildings – addressing indoor air quality, thermal environment, lighting and acoustics.

EN 15251 Comfort Categories

- **New categories**
- **Category II is assumed to be the 'norm'**

Category	Explanation
I	High level of expectation and is recommended for spaces occupied by very sensitive and fragile persons with special requirements like handicapped, sick, very young children and elderly persons
II	Normal level of expectation and should be used for new buildings and renovations
III	An acceptable, moderate level of expectation and may be used for existing buildings
IV	Values outside the criteria for the above categories. This category should only be accepted for a limited part of the year

Thermal comfort

Factors Influencing Thermal Comfort

- Human
  - **Metabolic Rate**
  - **Clothing Insulation**

- Space
  - **Air Temperature (Dry-Bulb)**
  - **Relative Humidity**
  - **Air Velocity**
  - **Radiation (Mean Radiant Temperature)**

Comfort measure: Predicted Mean Vote

-3	cold	dissatisfied – too cold	
-2	cool		
-1	slightly cool	satisfied	
0	neutral		
1	slightly warm		
2	warm	dissatisfied – too warm	
3	hot		

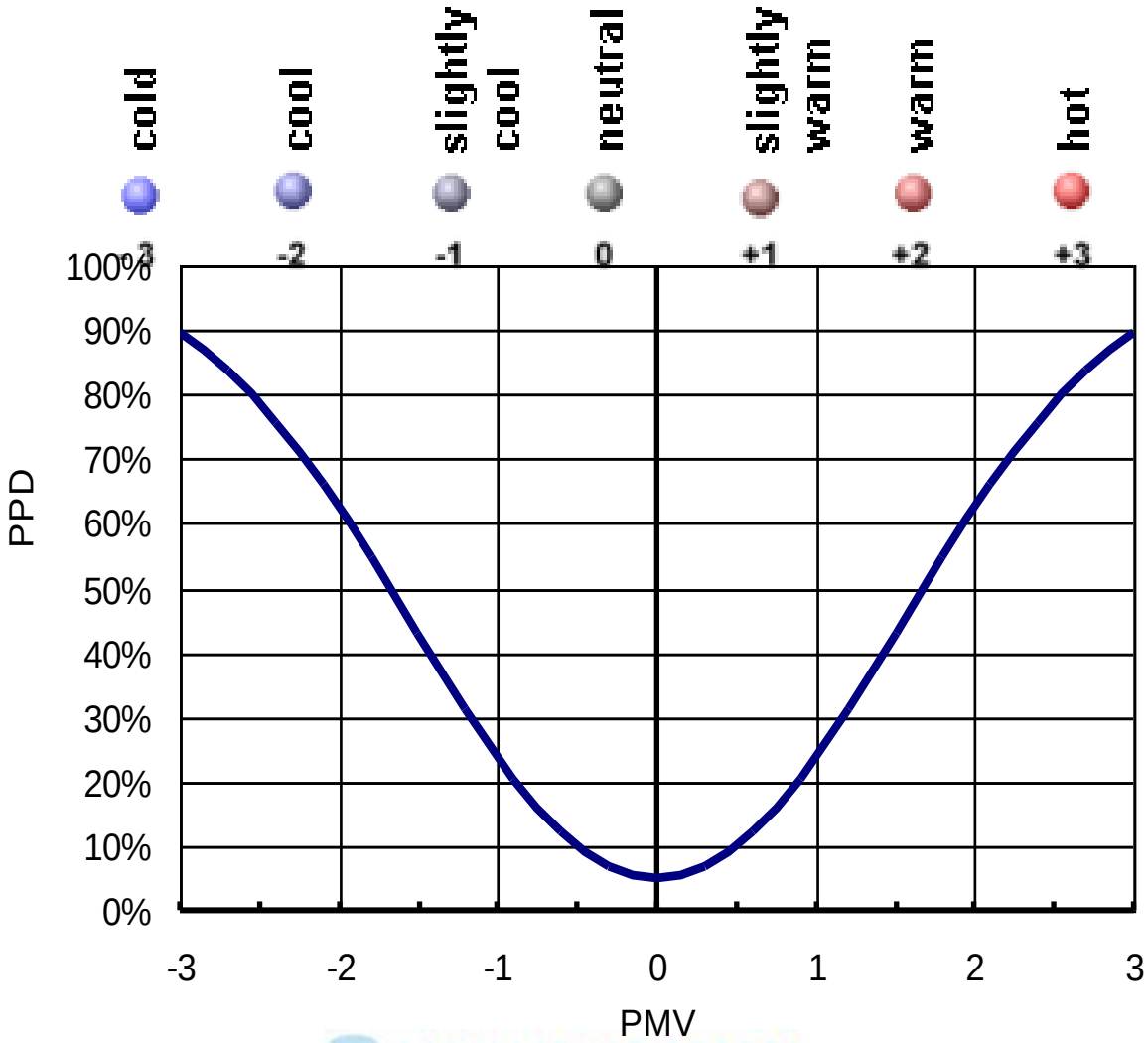
ASHRAE (1981) 55-81 standard	
Hot	+3
Warm	+2
Slightly warm	+1
Neutral	0
Slightly cool	-1
Cool	-2
Cold	-3

PMV and PPD index

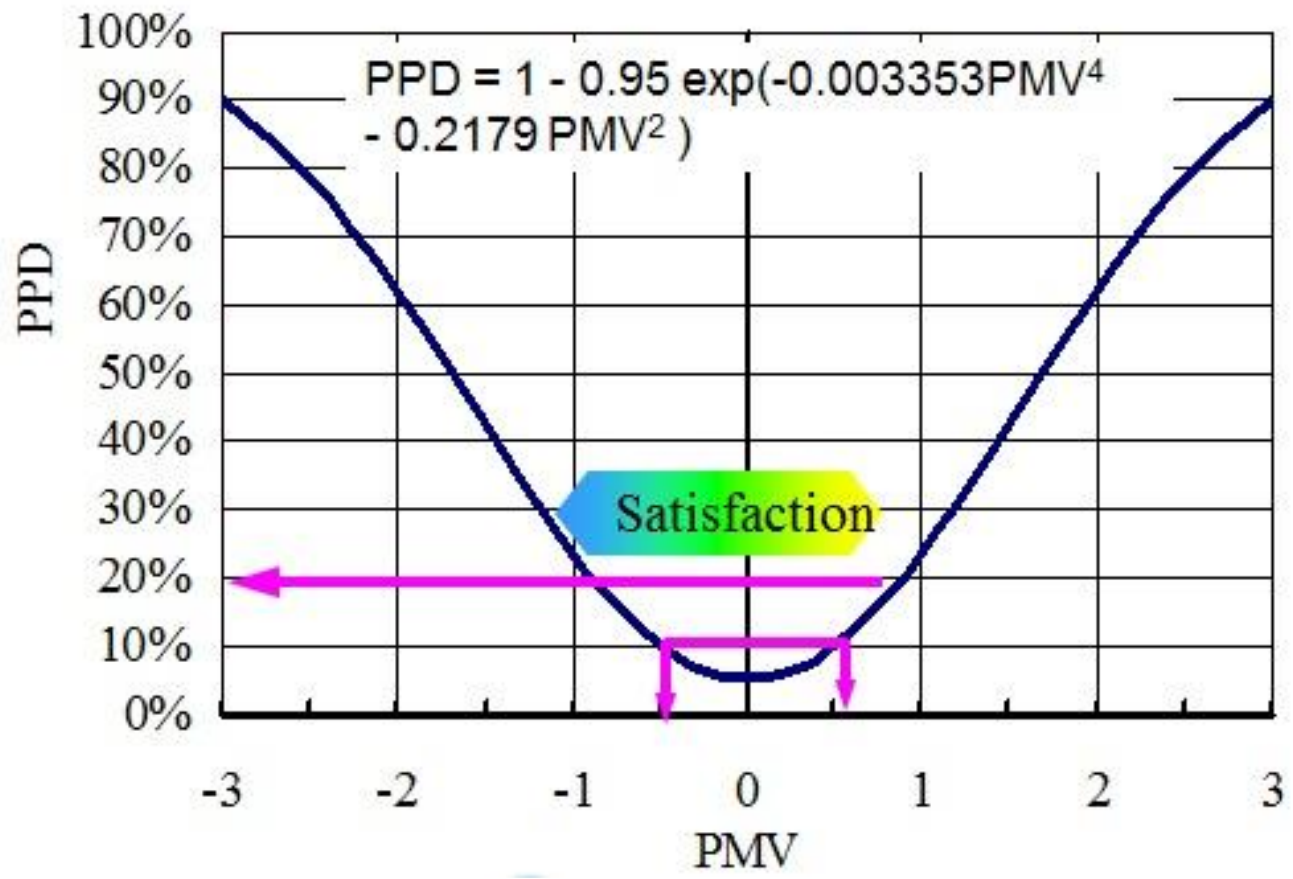
PMV index Predicted Mean Vote

PPD index Predicted Percentage of Dissatisfied

PMV and PPD index



PMV and PPD index



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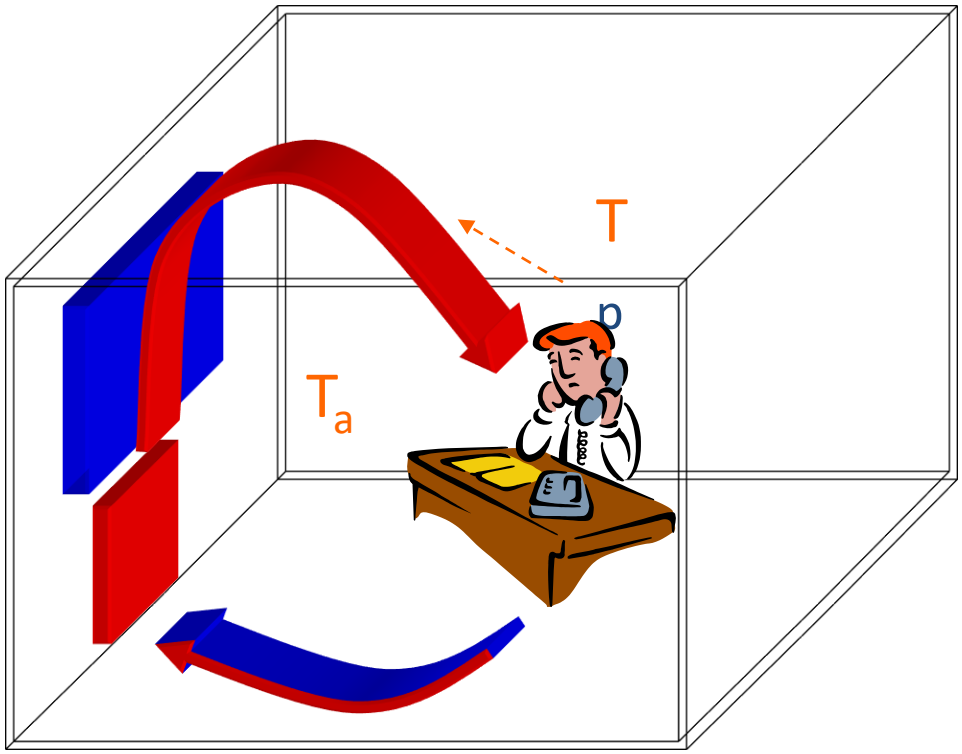
Heat Exchange between the Human Body and the Environment

- **Metabolic Rate M**
  - **degree of muscular activities,**
  - **environmental conditions**
  - **body size.**
- Heat loss Q
  - Respiration
  - Convection
  - Radiation
  - Conduction
  - Evaporation
- Body thermal balance equation

  M=Q comfort

  M>Q hot

  M<Q cold



Metabolic heat

M=H+W , where

M	metabolic heat
H	heat production
W	work

η=W/M

H=M(1- η)

1 met = 58 W/m²

Heat production of human body

$$\frac{H}{F_{Du}} = \frac{M}{F_{Du}} \cdot (1-\eta)\left[\frac{W}{m^2}\right]$$

Surface area of human body (Du Bois):

$$F_{Du} = 0{,}203 \cdot G^{0{,}425} \cdot L^{0{,}725}\left[m^2\right]$$

G mass of the person(kg)

L height of the person (m)

Thermal comfort

M - Metabolic Rate (m^2.K/W)

1Met = 58,15 W/m^2

Thermal comfort

I - Clothing Insulation (m^2.K/W)

1 clo=0,155m^2.K/W

clo <0,5

0,6-1,2

>3,5

Environmental indices

- **Air temperature t_a**

- **Mean Radiant Temperature t_{MRT}**

$$t_{MRT} = \frac{F_1 \cdot t_1 + F_2 \cdot t_2 + \ldots + F_n \cdot t_n}{F_1 + F_2 + \ldots + F_n} [°C]$$

where

- **F_i = surface area**
- **t_i = temperature of the surrounding surface i, i=1,2,....,n**

Environmental indices

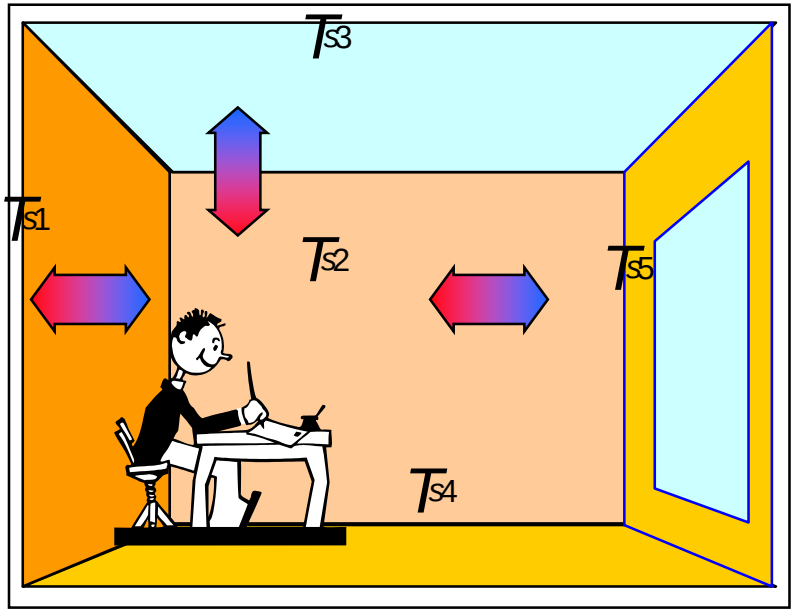
- **Mean Radiant Temperature**

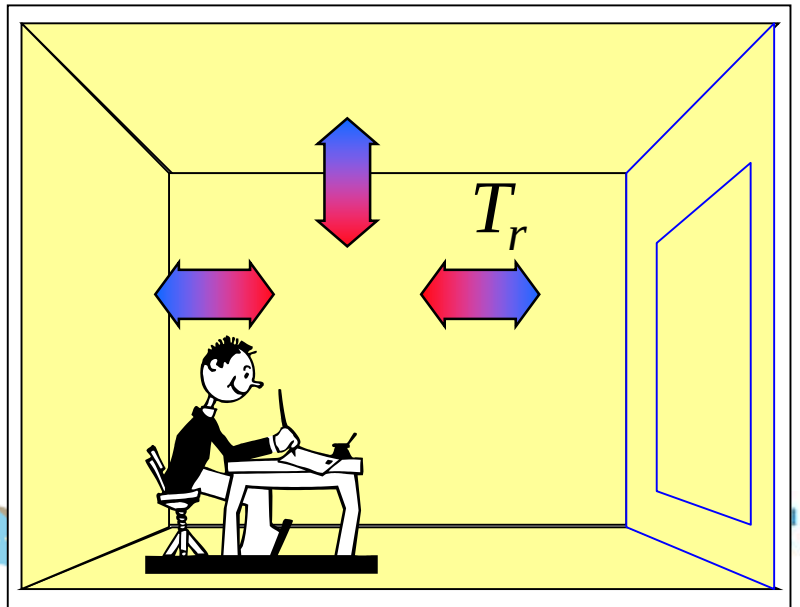
$$t_r = \sqrt[4]{\varphi_{rr1}.T_1^{\,4} + \ldots + \varphi_{rn}.T_n^{\,4}} - 273$$

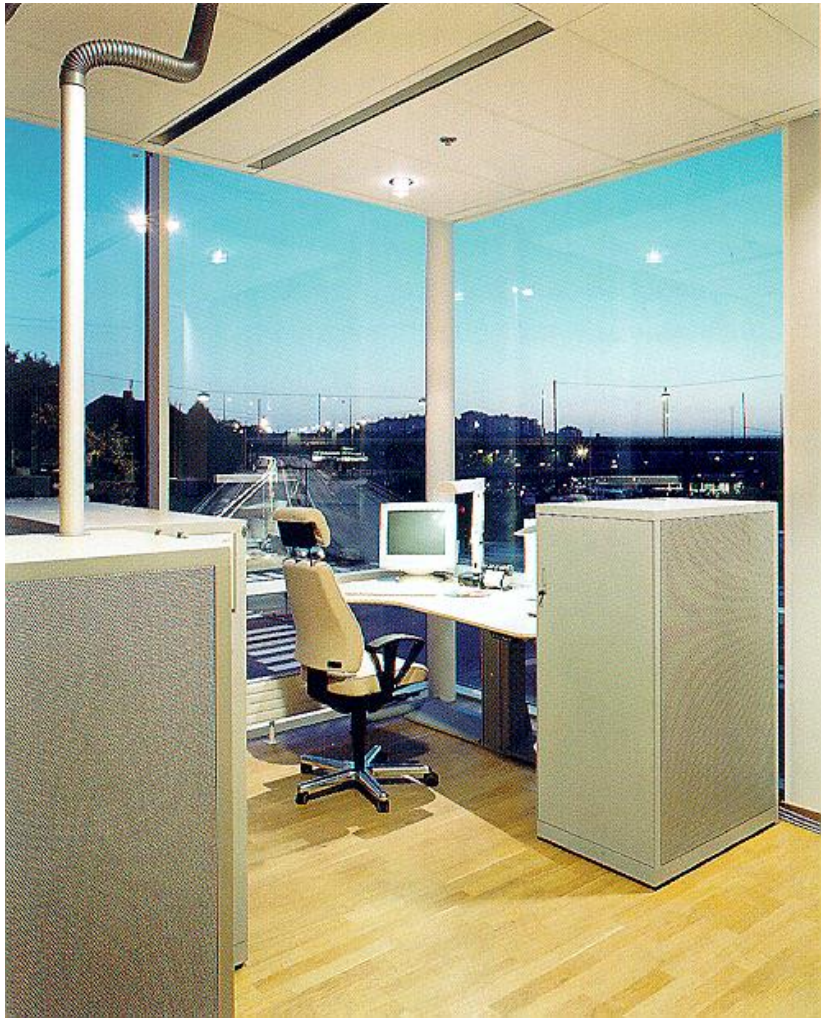
where

- **tr = mean radiant temperature**
- **Ti = temperature of the surrounding surface i, i=1,2,....,n**
- **φ_{rn} = shape factor which indicates the fraction of total radiant energy leaving the clothing surface 0 and arriving directly on surface i, i=1,2,...n**

Mean Radiant Temperature







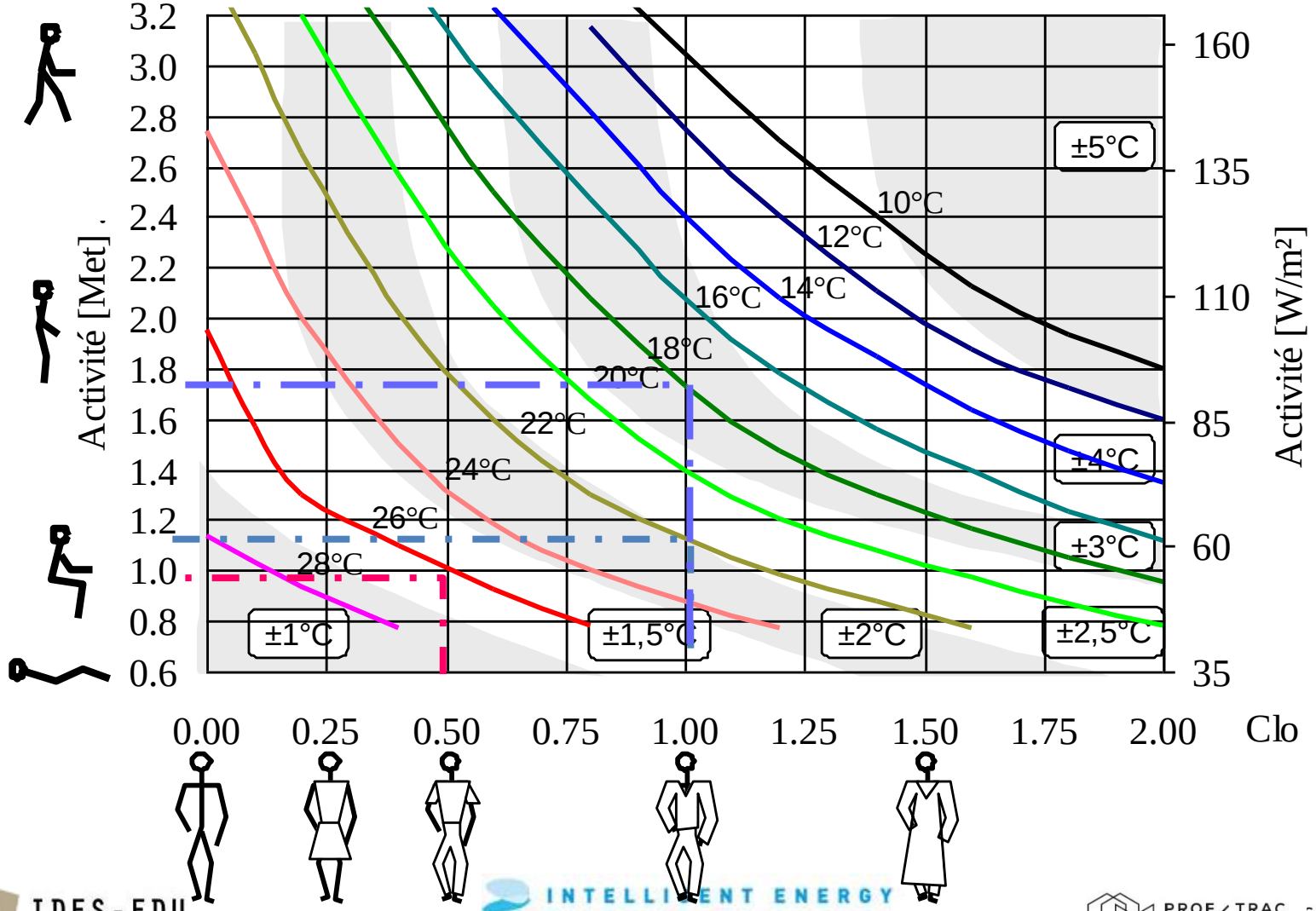
Environmental indices

- **Operative Temperature**

$$t_{op} = \frac{h_c t_a + h_r t_r}{h_c + h_r}$$

where t_{op} **= operative temperature**
t_a **= air temperature**
t_r **= mean radiant temperature (MRT)**
h_c **= convective heat transfer coefficient**
h_r **= mean radiative heat transfer coefficient**

Operative temperature

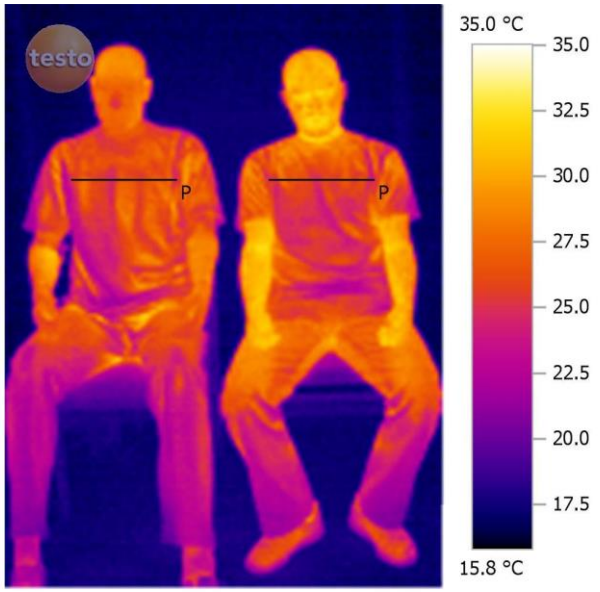


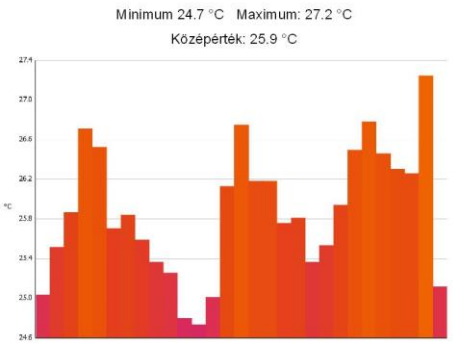
5. Temperature of the clothing

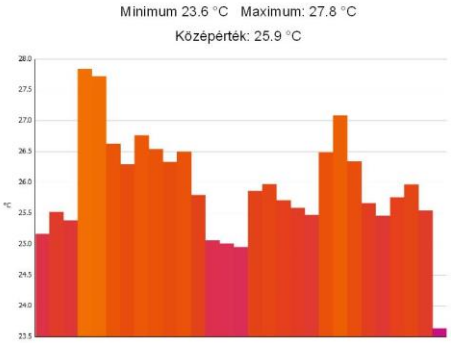
t_{cl}

6. Temperature of the skin

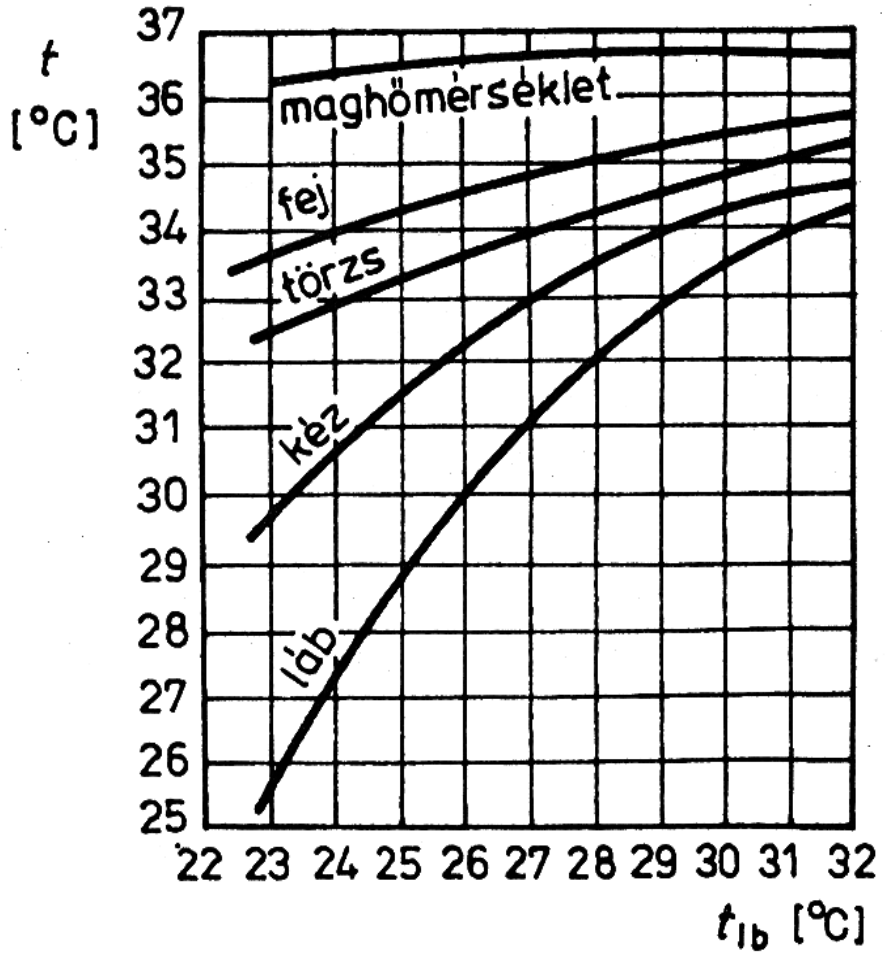
- thermovision
- measuring
- calculation
- diagram







Surface temperature of the different body part in function of the air temperature



(Bradtke and Liese, 1952)

- core
- head
- body
- hand
- leg

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Thank you the attention!

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