HEAT AND MASS TRANSFER

1. The first and second laws of thermodynamics; internal energy; enthalpy; heat; work; entropy.
2. The equation of state of an ideal gas; universal and specific gas constants (numerical values for air and water vapor); specific heat capacities (isobaric and isochoric).
3. Heat cycles: Carnot (ideal) cycle and Clausius-Rankin (non-ideal) cycles in pressure-volume (*p-v*) and temperature-entropy (*T-s*) diagrams; water-steam diagram (*T-s*, *p-v*); thermal efficiency of a cycle; heat pump cycle; coefficient of performance (*COP*); energy efficiency ratio (*EER*).
4. Analogy in molecular (diffusive) transport of momentum, heat and mass; diffusion coefficients – viscosity, thermal diffusivity, concentration (mass) diffusivity; basic laws (Newton's, Fourier's and Fick's), dimensionless similarity numbers (*Pr*, *Sc*, *Le*)
5. Heat transfer by conduction; Fourier's law; thermal conductivity and thermal diffusivity; steady-state heat conduction in a single-/ multi-layered plane/ cylindrical walls; range of values for thermal conductivity of building materials and insulations, metals, water and air; wall thermal resistance; overall heat transfer through a wall (plane or cylindrical); overall heat transfer coefficient (*U-value*).
6. Derivation of Fourier's equation of heat conduction, initial and boundary conditions.
7. Heat transfer by convection; conditions for the occurrence of convection; Newton's cooling law; classification of thermal convection; dimensionless similarity numbers (*Nu*, *Re*, *Gr*, *Pr*); thermo-kinetic boundary layer; heat transfer coefficient (range of values for liquids and gases, natural or forced convection).
8. Heat exchangers; classification; special flow arrangements (parallel-flow, counter-flow); temperature diagram; heat balance equation; heat rate equation; heat exchange effectiveness; mean temperature difference; heat balance equation and temperature diagram for evaporators or condensers.
9. Heat transfer by radiation; Planck's and Wien's laws for the spectral emissive power (diagram); Stefan-Boltzmann law for the total emissive power; Kirchhoff's law (emissivity and absorptivity).
10. Heat radiation by black surface, grey surface or real surface; classification of emitters (selective vs. non-selective, diffuse vs. directional); transmission, absorption and reflection of heat radiation; heat rate between two grey surfaces with high emissivities; view factor; mean radiant temperature in rooms.
11. Solar radiation; solar constant; direct and diffuse solar radiation; basics of solar geometry; impact of solar irradiation on an opaque or transparent construction; sol-air temperature; solar characteristics of glazing.
12. Water vapor transport; evaporation and condensation; water vapor diffusion and convection; basic laws and equations; dimensionless similarity numbers (*Sh*, *Re*, *Gr*, *Sc*); analogy in heat and water vapor transport (Lewis' correlation).

ENVIRONMENTAL ENGINEERING

1. State of the environment – outdoor environment, indoor environment (microenvironment).
2. Indoor environmental parameters and indices: dry bulb temperature, mean radiant temperature, operative temperature, globe temperature, PPD, PMV.
3. Heat balance of human body, sensible heat loss from skin, heat transport through clothing, evaporative heat loss from skin, respiratory losses, thermal comfort.
4. Air pollutants, sources of air pollution, measurement, exposure (imission) limits.
5. Calculation of heat losses, heat demand and fuel demand for heating.
6. Calculation of heat gains (cooling load) and cooling energy demand for air-conditioning.
7. Heat balance in a ventilated room, pollutant mass balance in a ventilated room
8. Natural ventilation, wind-pressure driven ventilation, buoyancy driven ventilation, intermittent ventilation by windows, infiltration.
9. Indoor air flow, aerodynamics of exhaust openings and hoods.
10. Ventilation systems.
11. Air-conditioning systems.
12. Air conditioning processes in *h-x* (enthalpy – humidity ratio) diagram of moist air.
13. Sizing of air-conditioning equipment.
14. Air flow in ducts, dimensioning of duct systems.
15. Performance characteristics of ventilation fans, fan sizing, control of fans.
16. Properties of dust, dust separation principles, dust separators and their performance characteristics.
17. Heat sources for heating, efficiency, standardized and annual degree of utilization (for boilers).
18. Heating systems, dimensioning methods for piping, pressure balance equation.
19. Heating appliances – heating output and sizing of radiators.
20. Predominantly radiant heating systems (underfloor heating system, wall heating, ceiling heating).
21. Heating and ventilation of large halls, radiant panels and strips, bright and dark radiant heaters (according to ASHRAE: low- medium- and high- intensity radiant heaters).
22. Control of air-conditioning and ventilation equipment.
23. Control of heating systems, control of heat sources (boilers and heat exchangers).
24. Noise and vibration control, noise sources, calculation principles and measurement.
25. Experimental methods in environmental engineering.

FLUID MECHANICS

1. Classification of fluids with respect to their properties (viscosity, compressibility), change of viscosity with temperature (gases vs. liquids), change of density with temperature (thermal expansion coefficient, buoyancy in fluids).
2. Material derivative and its application in fluid flow description, relation between general and material derivatives, local and convective (advective) term, material derivative of velocity in steady-state flow.
3. System of fundamental equations in fluid mechanics and their relation to the laws of conservation (mass, momentum, energy), nomenclature and mathematical classification of the fundamental equations for 1-D flow (in pipes) and for 3-D flow.
4. Derivation of Euler's equation (EE) of hydrostatic equilibrium, integration of EE in the Earth's gravitational filed, application in the calculation of stack pressure in buildings.
5. Derivation of the continuity equation (1-D flow in pipes, general case of 3-D flow)
6. Bernoulli's equation (BE) for 1-D flow in pipes, integral and differential form of BE, forms of BE (pressure, mechanical energy, head), terms in BE, BE vs. energy equation.
7. Transformation of static pressure into dynamic pressure and pressure loss (application of Bernoulli's equation), fluid flow from a large vessel through a small opening, discharge coefficient, buoyancy-driven flow in buildings and chimneys.
8. Pipe flow of viscous fluids; laminar and turbulent flow; velocity profile; mean velocity with respect to mass, momentum or energy transport; pressure loss (local and friction); significance of Reynolds number
9. Fluid flow in rotating channels, extended Bernoulli's equation, Euler's pump and turbine equation, radial pump, radial fan
10. 2-D potential flow, velocity potential, stream function, complex potential, basic potential flows (uniform flow, source/sink, vortex), calculation of velocity in potential flow, stream lines, superposition of basic flows (exhaust of contaminants, cyclone, radial fan, flow over a Pitot-static tube).
11. Euler and Navier-Stokes equations for incompressible fluid flow, identification of different terms (local, convective, pressure, buoyancy and viscous terms), boundary conditions at the wall surface.
12. Similarity and modeling of air flow in a ventilated room, classification (isothermal, non-isothermal, forced, natural), significant forces (inertial, viscous and buoyancy), dimensionless similarity numbers *Re*, *Ar*, *Gr*
13. Boundary layer, Prandtl's analysis of 2-D boundary-layer flow, laminar and turbulent boundary layer, viscous sub-layer and its interaction with the pipe wall roughness.
14. Turbulent flow, Reynolds decomposition and averaging (RDA), turbulence intensity, Reynolds turbulent stress (application of RDA on a convective term in Navier-Stokes equations), turbulent (eddy) viscosity