assigned February 21, 2006   due February 27, 2006

HOMEWORK #2
Heat and air flow

Questions

a. Verify the homogeneity of the units in Bernouilli's equation.

b. Why do we feel cold in water at 72°F but warm in air at the same temperature ?

c. What makes a plane able to fly ?

Problems

1. The wall of a building analyzed during the winter (exterior temperature 0°C, interior temperature 20°C) consists of the following sequence of layers :

    - dense concrete: 8 cm
    - dense mineral fiber: 4.5 cm
    - interior dense plastering: 1.5 cm

    Through which element (layer) do we observe the most significant drop in temperature? Use Data sheet D.1.1 of your textbook.
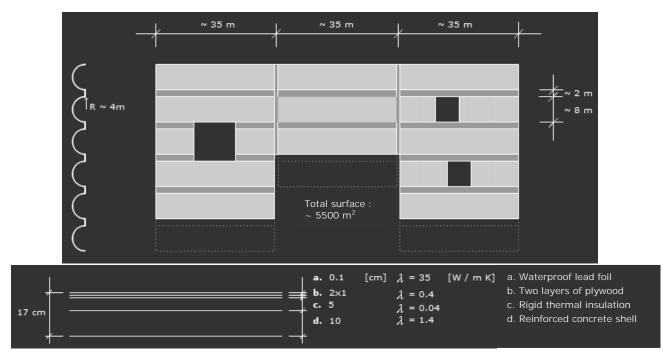
    Provide a graphical representation of the temperature variation from the inside to the outside, as a function of thickness then as a function of resistance.

2. A farm situated in the open countryside induces the wind flow's speed, equal to 120 km/h over the land, to be increased by 40% when passing over its roof, whose surface is 400 m².

    What is the total force applied on the roof, assuming that the inside and outside pressures are constant over the total roof surface and that the air is at 18°C and 97'325 Pa ? What should be the mass density (kg/m²) of the roof if we wanted to avoid it being lifted up without relying on it being attached to the bearing walls ?

3. The Kimbell Art Museum, located in Fortworth (Texas) and designed by Louis Kahn in 1972, appears as a sequence of linear adjacent modules, each supporting a thin roof shell presenting a slit along in their main dimension to allow natural daylight to illuminate the exposition halls.

Calculate the U-value of the roof shells using the geometric and conductivity data provided below.

				[cm]	λ = 35	[W / m K]	a. Waterproof lead foil
a.	0.1				λ = 0.4		b. Two layers of plywood
b.	2×1				λ = 0.04		c. Rigid thermal insulation
c.	5				λ = 1.4		d. Reinforced concrete shell
d.	10						

On a warm and humid day in August, the outside temperature was found equal to 90°F. What heat transfer [W] allows the recommended inside temperature to be reached (see ASHRAE table below)?
This value is to be calculated for both an individual shell (assumed of hemi-cylindrical shape) and for the entire roof. Heat is assumed to transfer through the roof only (heat losses/gains through the lateral walls are neglected).

Table 1 General Design Criteria[a, b]

General Category	Specific Category	Inside Design Conditions		Air Movement	Circulation, Air Changes per Hour
		Winter	Summer		
Dining and Entertainment Centers	Cafeterias and Luncheonettes	70 to 74°F 20 to 30% rh	78°F [e] 50% rh	50 fpm at 6 ft above floor	12 to 15
	Restaurants	70 to 74°F 20 to 30% rh	74 to 78°F 55 to 60% rh	25 to 30 fpm	8 to 12
	Bars	70 to 74°F 20 to 30% rh	74 to 78°F 50 to 60% rh	30 fpm at 6 ft above floor	15 to 20
	Nightclubs	70 to 74°F 20 to 30% rh	74 to 78°F 50 to 60% rh	below 25 fpm at 5 ft above floor	20 to 30
	Kitchens	70 to 74°F	85 to 88°F	30 to 50 fpm	12 to 15[h]
Office Buildings		70 to 74°F 20 to 30% rh	74 to 78°F 50 to 60% rh	25 to 45 fpm 0.75 to 2 cfm/ft²	4 to 10
Libraries and Museums	Average	68 to 72°F (20 to 22°C) 40 to 55% rh		below 25 fpm	8 to 12
	Archival	See Special Considerations in the section on Libraries and Museums		below 25 fpm	8 to 12
Bowling Centers		70 to 74°F 20 to 30% rh	75 to 78°F 50 to 55% rh	50 fpm at 6 ft above floor	10 to 15

Source : "1999 ASHRAE Applications Handbook (SI)", Chap. 3

4. The Phillips Exeter Academy Library, located in Exeter (New Hampshire) and designed by Louis Kahn in 1967-1970, is organized around an impressive central atrium of square section that is more than 20 m high.

During a cold winter day, the inside and outside temperatures have been measured and found to be 68°F and 14°F respectively.

Because the main building doors are constantly being opened and closed, the inside and outside pressures are equal at ground level. Calculate the pressure difference between inside and outside:

- at level 2 (1 storey up from ground i.e. 3 m from ground)
- at level 8 (7 stories up from ground i.e. 17.5 m from ground)

and deduce in what direction the air will flow in the atrium, explaining how you came to that conclusion.

NB: Relative density of air at normal conditions (0°C, atmospheric pressure):
ρ_{air}(0°C, 101325 Pa) = 1.293 kg/m³

Design Project

Get started

For the first part of your design project, you will be asked to establish the thermal balance of the building you have selected, for the climatic and solar radiation conditions applicable to early March in the Boston area.Thermal balance occurs when the sum of all the different types of heat flow into and out of a building is zero. The building is losing as much heat as it gains so it is said to be in equilibrium.

The components of heat gain and loss include:
* conduction gains when outside heat flows through the envelope
* ventilation gains when outside air enters the building
* solar gains when additional heat is provided by solar radiation
* internal gains resulting from internal heat sources
* and evaporative loss when water is changed into vapor

You will have to assess them for your particular building knowing what materials they were built of, what kind of insulation, envelope materials, and windows were selected for it, if there is natural ventilation and what kind of volumes are involved, what the wind and sun conditions are, what the building's orientation is, as well as its heating and cooling systems etc.

Therefore, you will need to gather a lot of data before being able to start calculating the flows. Start now gathering these data from literature references about your building, from asking people living/working there, from your own deductions or from reasonable estimations if the precise data cannot be found.

You will be considering the whole building, thus you will not be able to account for all parameters accurately. The idea of this exercise is to bring you to make reasonable assumptions and deduce realistic values, so that you can assess the thermal aspects of your building as a whole.

By February 27, you are expected to hand out a **list of data** that you **plan to collect**, with the corresponding **resource** you plan to use to get this information (book, internet, building plans, interview of occupants, measurement, calculation).If any, also point out any critical information you don't think you will be able to find.

Reading assignment from Textbook:

"Introduction to Architectural Science" by Szokolay: § 1.1.1 - 1.1.2 + § 1.1.4 + § 1.4.1 - 1.4.2

Additional readings relevant to lecture topics:

"How Buildings Work" by Allen: pp. 47 – 51 in Chap 8 and Chap 11
"Heating Cooling Lighting" by Lechner: Chap 3
"Sun Wind Light" by Brown & DeKay: § 6 in Chap 1A