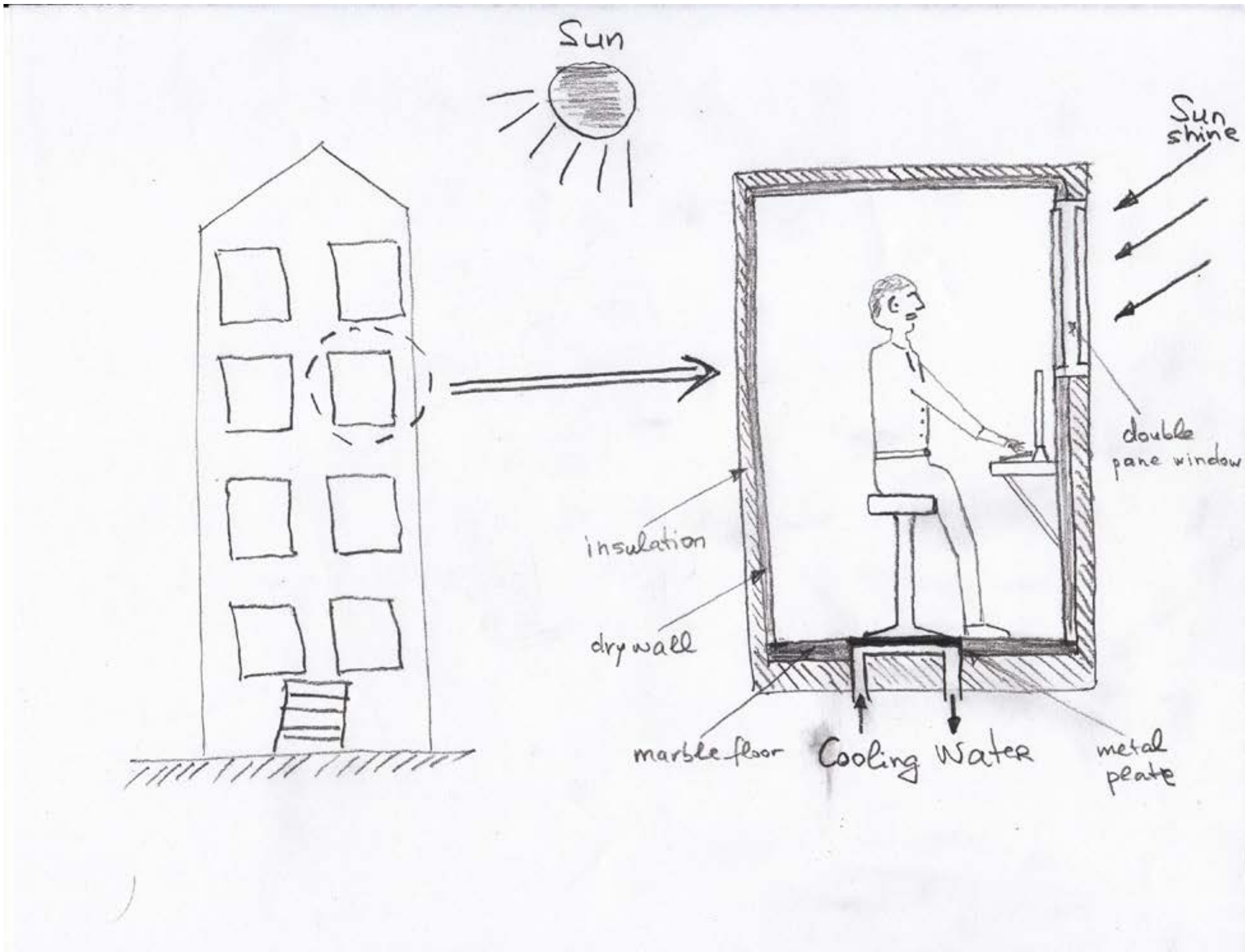
FINAL EXAM (**30 pts**) constitutes an open-ended thermal design problem, which involves all modes of heat transfer. The problem solution can be submitted for feedback/grading at any time and as many times as you want during the semester. You could use any resources you want for working on the problem. <u>The deadline for final submission is the last day of classes (Dec. 5, 2017)</u>.

Consider a room in a big, multi-store office building, as shown in Figure 1 (next page). Air conditioning (AC) of such a building in its entirety is very expensive and results in significant maintenance costs during the Summer season. To mitigate the AC cost, an engineering design firm proposed a novel approach of "local cooling", which aims to provide thermal comfort for an office worker locally at its desk. Studies in human physiology suggests that the temperature experienced by a person in his/her forehead area is the best "single point" indicator of the person's comfort, with a 23-25^{o}C temperature range corresponding to the state of most comfort.

Central to the proposed approach is utilization of discrete "cold spots" (a 50 cm in diameter, 1 cm thick aluminum disk cooled from beneath using a microchannel flow of chilled water) mounted on the floor of each room/office. The "cold spot" temperature can maintained at any level, as desired by changing the temperature of the chilled water. To take advantage of the "local cooling", an office worker would situate the base of his chair on top of a "cold spot" (as shown in Figure). The main interior and exterior components (walls, ceiling, floor, double-pane windows) that are important for the analysis are shown in Figure 1, and you can choose their dimensions and specific materials based on acceptable construction practices. The solar irradiation results in a heat flux ~1,370 W/m^2 incident onto the room window at an angle varying between 30 and 60 degrees, depending on the time of the day. Also important for the analysis is that a normal metabolic rate of a typical human is about 100W. *The goal of your analysis is to determine the "cold spot" characteristics ensuring a person's comfort, including (1) the required temperature of the "cold spot", (2) the total thermal load (in Watts) that the cooling water must be able to remove, (3) the inlet temperature and (4) required flow rate of cooling water if its temperature rise between the inlet and outlet should not exceed 10^{o}C*. You could choose any other system dimensions, parameters, and properties that have not been specified in the problem statement, based on what is reasonable and provide an appropriate justification.

1. Setup the problem in heat transfer terms by breaking a system into relevant sub-systems with identification of heat transfer modes and interactions/coupling between sub-systems (at all boundaries) [**10 pts**]
2. Make and justify simplifications for each sub-system to be analyzed based on relevant dimensions and thermophysical properties of materials, which should be listed along with the source of information. <u>Use SI units only!</u> [**5 pts**]
3. Develop appropriate governing equations (algebraic or differential) for different sub-systems using the appropriate heat transfer balances, consistent with on heat transfer mode identification and assumptions made in parts 1 and 2 above [**10 pts**]
4. Describe an approach/algorithm for solving the governing equations you developed in part 3 in a step-by-step manner to clearly show how the quantities of interests (see the problem statement above, italicized) will become determined. The number of equations must be equal the number of unknowns for the problem to have a unique solution. [**3 pts**]
5. Using your algorithm in part 4 and representative values for the system dimensions and thermophysical properties (based on your selection of materials), compute the four quantities of interest (see the problem statement above, italicized) for the "cold spot" designer. Discuss the results and comment on feasibility of the localized cooling approach. [**2 pts**]


Sun
Sun shine
double pane window
insulation
dry wall
marble floor
Cooling Water
metal peate