SECTION 5: TECHNICAL REQUIREMENTS

Environmentally conscious design intentions are only successful when they actually improve building performance. Several techniques are available that allow building designers to predict the performance of a proposed structure in order to test the impact of modifying specific components of the building. The Leading Edge Competition gives students the opportunity to experience the process of evaluating and improving their designs using analytical methods. The analyses can be simple calculations done by hand, or sophisticated computerized performance modeling methods. Competition entrants are urged to consider using an energy modeling program to study the performance of their designs. Many energy modeling programs are available, and any that adequately model the conditions of the project are acceptable.

Students in Challenge 1 must complete three of the calculations in Part I **or** complete the performance simulation model in Part II. Those entering Challenge 2 must do one of the following 5 technical calculations in Part I, **or** complete a performance simulation model in Part II.

Summaries of the results of the technical tasks must be presented on the front of the entry boards. The technical analyses should be included in the narrative, and the ways the design was changed to improve its performance in response to the results of the technical analysis should be discussed.

The detailed worksheets and calculations required for each task must be written or typed on 8-1/2″ x 11″ inch paper and placed in an envelope attached to the back of the presentation boards. *Indicate clearly on each sheet your registration number and which analysis is being performed.* Neatness counts. All the steps of the calculations should be presented concisely with graphic clarity. If the judges cannot follow your calculations or understand your conclusions, you will not receive credit for completing the technical tasks.

As stated in the discussion of the Narrative in Section 4: Submission Requirements, on page 4-1, you must show how your design was influenced by the results of your technical analysis. The judges are looking for more than the correct completion of the technical tasks; they are also looking for how that information influenced your design.

Students completing a building performance simulation model are encouraged to provide graphic evidence of the results of their model on the face of the board. However, more detailed results of the simulation may be attached in an envelope on the back of the board.

Part I: Technical Analysis Tasks

Reference: **Throughout these exercises, page and table numbers refer to *Mechanical and Electrical Equipment for Buildings* (MEEB)** by Benjamin Stein, John S. Reynolds, Walter T. Grondzik, and Alison G. Kwok, 2006, Tenth Edition, John Wiley & Sons, New York.

1. Heat Losses and Thermal Performance of the Building Envelope

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Objectives: To investigate the relationship between the physical characteristics of a building's envelope and its thermal performance.

Format: Drawings, sketches, diagrams and concise written summary.

Tasks: **Envelope Heat Loss Coefficient:**

1. Show the construction of each portion of the building in a section identifying all the materials in the envelope of the building and their thermal properties (see MEEB Appendix tables E.1 – E.14, pp. 1549-1584). The wall section required in Section 4, Submission Requirements, may be used as one of the building wall sections.

2. Complete a *Building Envelope Summary Table* showing the R values for each component and the total U value for each of the wall sections prepared in step 1.

3. Calculate $UA_{envelope}$ (heat loss coefficient through the envelope, Btu/hr ^{o}F) by totaling:

U x Area, for each element in the building envelope

4. Calculate the equivalent $UA_{infiltration}$ (heat loss through infiltration, Btu/hr ^{o}F) as follows:

$UA_{infiltration}$=ACH (#/hr) x 0.018(Btu/ft^{3} ^{o}F) x building volume (ft^{3})

ACH = air changes per hour due to infiltration. Determine the approx. ACH for your building using MEEB Section 7.7a (pp. 202-203) and Appendix Table E.27 Parts A and B (p. 1601). The Volumetric Heat Capacity of air is: 0.018 Btu/ft^{3o}F.

5. Calculate the $UA_{ventilation}$. (Challenge 1 entrants only)

UAventilation = (#occupants) x (0.018 Btu/ft^{3} ^{o}F) x (15 ft^{3}/min. occupant) x (60 min/hr)

6. Calculate the *heat loss coefficient* for your building (UA_{total}):

Total Heat Loss Coefficient (Btu/h ^{O}F) = $UA_{envelope}$ + $UA_{infiltration}$ + $UA_{ventilation}$

Heat Loss through the Envelope:

7. Use the heat loss coefficient (UA_{total}) calculated above or total heat loss rate, to calculate (estimate) the annual heating-season fuel consumption (MEEB Section 8.9, pp 256-259)

- Choose an appropriate HDD (heating degree day) value for your building.
  For the building, annual fuel consumption will be affected by how many sources of interior heat gain are present in your building. Lights, people, equipment, etc., all contribute heat to the interior of the building. You can allow for this in the selection of an appropriate Heating Degree Day value (DD). We have included the HDD values for Santa Barbara in the Weather and Climate Information Section. The greater the internal sources of heat in your building, the more you should tend to use DD50 instead of DD65 to estimate annual fuel consumption.
  These issues are less important for residential structures which tend to be dominated by heat loss and not interior heat gains

- Annual Heating Fuel Consumption (E):

$$E = \frac{UA\ (Btu/h\ ^{O}F) \times DD\ value\ (^{O}F\ day) \times 24 (h/day)}{(AFUE)V}$$

  UA is the total heat loss from step 6. AFUE is the Annual Fuel Utilization Efficiency from MEEB Table 8.7 (p.258).

- Convert this annual heating Btu total to actual units of fuel (KWhr, therms, etc.) using Table 8.5 Approximate Heat Values of Fuels (p.255, MEEB), and compare the differences between the amount of fuel consumed *before* and *after* making energy conserving design changes.

2. Heat Gains and Thermal Performance

Objectives: To gain an understanding of the various sources of heat gain, and to see how these gains affect a building's thermal performance; to learn how to select an appropriate passive cooling strategy based on the climate type in which the building is located.

Format: Drawings and calculations should fit within an 8-1/2" x 11" area

Tasks: **Calculate Building Heat Gains:**

1. Using Appendix Table F.3: *Estimating Summer Heat Gains* (pp. 1610-1611, MEEB) calculate the approximate heat gains (BTU/hr ft^2) for your building. Calculate separately total heat gains for "open" strategies (Table F.3 Parts A, B, and C) and "closed" strategies (Parts A, B, C, and E).
Use Santa Barbara weather data summarized on the first page of Section 6, Weather and Climate Information for the outside design conditions. These data are from ASHRAE "Climate Data for Region X" and The California Energy Commission, Climate Zone 6. *The design dry bulb coincident mean wet bulb is 83/67 degrees Fahrenheit for the 0.5% level (used for "average" projects).* These conditions are typically exceeded only 44 hours/year.

2. Appendix Table F.3, *Estimating Summer Heat Gains*, assumes your building has external shading. Describe and document what kind of external shading devices you are providing for your building in summer. These devices should allow for good daylighting and for solar gain if it is needed during the winter heating season. Note that not all building types require winter solar gain.

Determine Appropriate Passive Cooling Strategies:

3. Find the minimum and maximum temperature and relative humidity for the months of May through October for your location.
Use the weather data provided in the Weather and Climate Information Section.

4. Plot min. temp/max. RH and max. temp./min. RH on Fig. 4.12: *Passive Cooling Design Strategies by Climate* (MEEB, p. 99). You may need to plot these on four separate graphs for clarity. Connecting these points will give you the range for the month.

5. Based on the plots on Fig 2.13, identify all of the passive cooling strategies that are appropriate for each month.

6. Identify and illustrate the cooling strategies that you have selected for your project and demonstrate how it responds to the conditions of the climate.

3. Sun Penetration and Solar Control

Objectives: The thermal and luminous performance of any space will be greatly affected by how well heat and light from the sun are utilized and controlled. In this investigation you will demonstrate the use of sun and light in the residence at different times of the year.

Format: Drawings or photographs.

Tasks:

1. Use a LOF Sun Calculator or other device to determine the altitude, azimuth, and most important the profile angle of the sun at 9 a.m., noon and 3 p.m. on the Winter Solstice (December 21), the Spring/Autumn Equinoxes (March/September 21), and the Summer Solstice (June 21).

2. Select a representative south, east, and west window in the building. Illustrate the sun penetration/solar control by:

   - creating simple and clear sections and/or diagrams of the window, illustrating the sun penetration/solar control provided by the aperture and shading devices. In this diagram, show the solar altitude angle and how the overhang or shading mechanism shades the window.

   OR

   - constructing a model of a portion of your building with all openings, shading devices, and interior walls. The model should be big enough to photograph the interior (i.e. 1/2" = 1'-0"). Mount your model on a cardboard base large enough to include a *Sun Dial Shadow Chart* (see MEEB, Appendix D pp. 1535-1538). Use photographs to illustrate the sun penetration at the given times.

3. Write a clear and concise *analysis* and *summary* of this investigation addressing, at a minimum, the following issues:

   - Evaluate the relationship between the sun patterns and your building's activities. How do your specific sun patterns affect the building's daylighting requirements? Speculate on the affect of the sun patterns on the buildings need for heating and cooling.

   - Does your design adequately avoid or block the sun in warm weather and admit sun in cold weather?

- Challenge 1 entrants: Does your design provide reflected daylight for the classrooms without allowing troublesome direct beam penetration?

4. Heat Gains and Losses through Windows

Objective: To study the issues of heat gain and loss as a result of sunlight striking south facing glass (thermal performance of glazing).

Overview

- Apply the concepts of U-values, ΔT, and Ta.
- Study the relationship of geographic location/latitude on solar gain;
- Show how window performance relates to window type.

Tasks: **Heat Gains:**

1. Determine heat gain (Btu/ft^{2}day) through the south facing glass using Solar Insolation Data. Use the average insolation on a vertical surface value (VS) for January, listed in Appendix C, Table C.15 (MEEB, pp. 1520-1525). "VS" is given as Btu/ft^{2}day, so you will have to multiply this number by the window area. Since Santa Barbara is not included in the table, use the entry for Santa Maria, CA.

Heat Losses:

2. Determine heat loss (Btu/ft^2 day) through the south facing glass as follows:

$$\textbf{Heat Loss (Btu/ft}^2\textbf{ day)} = \textbf{U}_{\textbf{window}}\textbf{ (Btu/hr ft}^2\ ^o\textbf{F) x 24 (hr/day) x }\Delta\textbf{T (}^o\textbf{F)}$$

(This will give you the heat loss per square foot of south facing glass which must then be multiplied by the window area to determine heat loss through all the south facing glass.)

The U-value of your windows can be found in Appendix Table E.15 (pp. 1585-1586, MEEB)

Ta (average daily temperature in degrees Fahrenheit) for Santa Barbara can be found in the weather information included in the Weather and Climate Information Section.

Determine (or assume) an average indoor temperature, in your building, for a typical 24 hour period in January, then calculate ΔT in degrees Fahrenheit where:

$$\Delta\textbf{T = (avg. indoor temp) - (Ta)}$$

Analysis and Summary:

3. Write a clear and concise *analysis* and *summary* of this investigation addressing, at a minimum, each of the following issues:

   - Comment on the comparison between heat gain and heat loss. On a typical January day, is there a net loss or a net gain?
   - How would better windows (lower U-value) affect the results?
   - Speculate on how the south-facing windows will perform in the summer.

5. Embodied Energy Calculation

Objective: Knowledge of the energy embodied in building materials (their extraction or harvest, manufacture and transportation) is an increasingly important part of sustainable design. In order to utilize materials that have the lowest impact on the environment, designers must appreciate the embodied energy in every material they use, and the regional variations in these values. The objective of this exercise is to quantify the embodied energy in the building envelope you have chosen for your design.

Overview Calculate the amount of embodied energy in wall and ceiling sections of the building.

Format Drawings and calculations that fit within an 8-1/2" x 11" space

References: Other references for Embodied Energy Calculations:
The American Institute of Architects. **AIA Environmental Resource Guide**, 1996, John Wiley & Sons. New York.
Hannon B., Stein, R., Segal, B., and Serber, D. **Energy Use for Building Construction**. 1977. Center for Advanced Computation, Univ. of Illinois. Champaign-Urbana, IL.

Tasks: **Calculate Embodied energy in the building envelope**

1. Show the construction of each portion of the building envelope of a typical dwelling unit in a section identifying all the materials in the envelope of the building.

2. Tabulate the embodied energy of each component of the building envelope per square foot of surface area. Use the values in Table 2.4 page 34-35 of MEEB.

3. Using the values of embodied energy per square foot of each envelope section, calculate the total embodied energy (BTUs) for the building envelope.

4. Write a concise *analysis* and *summary* of this investigation addressing the impact of different envelope materials choices on the total embodied energy in the building envelope. Discuss envelope materials you chose in terms of their energy efficiency performance in the building compared to the embodied energy it takes to extract and manufacture the material. Are you making good choices of materials?

Part II. Building Performance Simulation Model

Challenge 1 entrants will model their building design with an energy simulation tool of your choice. Focus on the performance of the classroom shown in your detailed floor plans. Challenge 2 entrants will model one residential unit of your choice. Challenge 1 entrants should use a nonresidential simulation tool since these spaces are internally loaded and do not have heating and cooling needs similar to residences. Consult with your instructor in choosing a building energy modeling program.

1. Model a base case building, which meets basic energy efficiency standards. Compare your design to the base case structure. Show how 3 or more of the changes from the base case improved your design's energy performance.

2. Demonstrate the results of your energy simulation model by including charts, graphs or other outputs that illustrate the energy performance of the building as part of your presentation. Some of these outputs may be included in the graphic presentation, however, a complete set of outputs should be included in an envelope attached to the back of the boards.

3. Include a brief written analysis describing the simulation program that you used and summarizing and interpreting the results. Discuss the **design changes** that were made to improve the energy efficiency of your building above the base case. What other changes could be made to the building to improve its performance?