ECT 212
COURSE

LANEY COLLEGE
ENVIRONMENTAL CONTROL TECHNOLOGY

Commercial HVAC Systems Program

ECT 212 Testing, Adjusting and Balancing

Courtesy of National Science Foundation – BEST Center
www.BESTctr.org

Updated 12/1/2016

ENVIRONMENTAL CONTROLS TECHNOLOGY

Course Documentation

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Career and Technical Education Division
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Catalog description

Introduction to the theory and practice necessary to properly test, adjust and balance HVAC systems including air and water systems. Develop proficiency in the use of instruments to properly balance the systems.

Lecture Hours: 25.5

Laboratory Hours: 25.5

Units

Semester Credit Hours: 2

Entry skills needed

- Co-requisite ECT 22 – Commercial HVAC Systems
- College-level reading and writing skills
- College-level math skills

Syllabus

See Appendix A for sample syllabus, course schedule, and policies. For lesson topics to include in course, see Exit Skills.

Student learning outcomes

Airflow Measurement

Demonstrate the ability to measure and adjust system airflow using anemometers, balometers, pitot tubes, and fan curves.

Waterflow Measurement

Demonstrate the ability to measure and control system water flows using circuit setters, flowmeters and pump curves.

Report Preparation

Demonstrate the ability to prepare typical balancing documents and compile a system balance report.

Terminal Unit Balancing/Commissioning

Using single and dual duct VAV terminals, calibrate flows and verify sequence of operations.

Exit skills

Course content to achieve outcomes listed above:

1. Demonstrate the ability to measure system airflow using anemometers, balometers, manometers, pitot tubes, tachometers and velometers
2. Demonstrate the ability to measure and control system water flows using circuit setters, flowmeters and pump curves.
3. Demonstrate the ability to prepare typical balancing documents and compile a system balance report
4. Demonstrate the ability to provide data appropriate for setup, commissioning and/or diagnosis of VAV terminal units.

Course materials

Principal text

HVAC Testing, Adjusting, and Balancing Manual, 3rd Edition, by John Gladstone and W. Bevirt, sponsored by the National Environmental Balancing Bureau, McGraw Hill - Publisher

Lecture materials and handouts

This course is strictly an overview course and makes significant use of online resources.

Additional Handouts:

1. Velocity Pressure to Velocity Table
2. Pitot Tube details and cutaway
3. Round Duct Traverse parameters/insertion distances
4. Aerocross Application Guide
5. Air/hydronic Flow Measurement Types Chart
6. Airflow in Ducts data (flow, p.d., velocity) Chart
7. Sample Forms for recording test data (based on NEBB requirements)

8. Sample fan curves and pump curves (manufacturer's data)

Other reference materials

None required

Software needed

None required

Lab setup and materials

- Laboratory air handlers with installed ductwork and terminals
- Duct installed test points for measurement of air flow (preferred)
- Rectangular and round ducts sized for various velocities
- Flat surface measurement points for practice with propeller type anemometers
- VAV (pressure independent) terminals
- Purpose built trainers
- Outlet diffusers in sizes that match balometer "cones" (student built)
- Variable speed devices on air handlers
- Installed pumps with suction and discharge gauges or pressure taps
- Variable speed devices on some pumps
- Circuit setters installed on coils
- Available fan curves and pump curves for installed equipment

Air Handler #5

Circuit Setter

Airflow Trainer

Traverse Test Point

Equipment & instruments required

- Manometers, U-tube, inclined draft and digital
- Pitot tubes, static pressure tips and tubing
- Hot wire and propeller type anemometers
- Balometers
- Installed turbine flowmeters
- Tachometers
- Hydronic manometers
- Ultrasonic flowmeters
- Ammeters (clamp-on)

Sample laboratory assignment

LANEY COLLEGE
Environmental Control Technology
Testing, Adjusting and Balancing

Laboratory Exercise #2

In this lab, you will work in small groups, measure airflow in a test lab air handling system, and complete sample NEBB forms to make up a small air balance report. Report your findings as a group. Each report should have at least 3 forms:

1. Test, Adjust and Balance Cover Sheet
2. Duct Traverse Test Report (Round) for appropriate duct size
3. Air Outlet Test Report

<u>Outcomes:</u>

1. Demonstrate the ability to measure system airflow using pitot tubes, velometers and/or hot wire anemometers and system outlet measurements using a balometer.
2. Demonstrate the ability to review measurement data and correctly complete sample TAB forms.

<u>Procedure Notes:</u>

1. Always review the manufacturer's instructions for the instrument you will be using.
2. Observe all lab safety rules, particularly when using ladders.

3. Use the back of each form for any calculations you need. Keep the front of the forms for "clean data."
4. Only one report per group is needed.

> First, complete the TAB mini report cover sheet using the following information:

- The Project is "Airflow Measurements – 2"
- The lab no. is -> 2
- Leave "PBE Name" blank
- Indicate the group number assigned in class
- List the other members of your group

In this lab, you will first take measurements of airflow in a major branch of one of the air handlers in the lab. Then you will measure the airflow in all of the supply air registers on that branch of the air distribution. The airflow in the main duct should equal the sum of all the airflow coming out of the registers.

Exercise A - **Perform a Duct Traverse and complete the Test form:**

1. Perform a duct traverse using a pitot or hot-wire traverse on the discharge side of the ACU #1 or ACU #2, at a designated spot, in one of the major branches. See the drawings you did in the first week if needed.
2. Perform an 8 point traverse using the form for the appropriate duct size. Use insertion distances on the form. Record your measurements in the figure on the form.
3. On the top of the Laney/NEBB form, transfer information as needed from the title sheet, and indicate the instrument you are using. For "System," use the fan number (e.g. AHU1, AHU2…) For "Lab Station," use the fan number and "left" or "right" for the branch of the fan you read, when looking from the fan (like "AHU2-Left").
4. In the "Duct Size" column, compute the duct (cross sectional) area in square feet and measure the static pressure at the place you will be taking the measurements.
5. Leave the "Design CFM" space blank.
6. In the "Actual CFM" space, compute the overall airflow using the FPM (avg) and the "Duct Size/Area" using the formula $Q=V_{avg} \times A$.

Exercise B **– Read Outlet Airflow using the Balometer:**

1. Using a balometer, read the airflow at the outlets on the branch of the air handler you previously measured.
2. On the "Air Outlet Test Report", transfer project name and system designation from prior forms. Identify the outlets on the drawings you did in the first week, and use those ID's on the "OUTLETS" columns on the form. You do not have to enter an A_K.
3. Measure the volume at all outlets. Indicate with an "X" that the readings were taken with a balometer in the "READINGS/Balometer" column.

4. In the "Flow" columns, enter the balometer readings in the "Actual" column. You do not have to fill in the design data columns.
5. In the Final columns, enter average velocity and flow if you are using the velometer. If you use the balometer, you may just enter the balometer reading.

REVIEW YOUR TEST FORMS BEFORE TURNING THEM IN, AND MAKE SURE THAT THE READINGS "MAKE SENSE". Your report should have at least 3 sheets, a Cover Sheet, a Duct Traverse Report and an Air Outlet Report. <u>Only one report per group is needed.</u>

<u>Reference Text Chapters:</u> "HVAC Testing, Adjusting, and Balancing MANUAL"

- Chapter 7, "Using TAB Instruments-Airflow"
- Chapter 18, "Recording TAB Data", page 239

Project

LANEY COLLEGE
Environmental Control Technology
Testing, Adjusting and Balancing

PROBLEM-BASED PROJECT

<u>Project Description</u>: <u>Laney Bistro HVAC Control Design</u>

In this project, working in small groups of 3 or 4, you will prepare a control design package for one of the air conditioning systems serving the Bistro and "Beginner's" Kitchen. Two groups will prepare a control package for the dining area of the Bistro. The other two groups will prepare a package for the kitchen portion of the project. Although the kitchen portion has multiple supply and return air handlers, the kitchen design group can use one system of supply and exhaust as typical. The paired fans groups are:

- AHU-1 and Exhaust Fan (variable speed)
- Make-up Air Unit (MAU) & Kitchen Hood Exhaust (multiple MAU's & Exhaust)

The design must address a problem that has developed since installation of the systems, that problem being unusually high pressure differences between the Bistro eating area and outside. The control design should maintain moderate pressure relationships and provide information to the operators on the status of the relative pressures in the eating area, kitchen and outside. It is suggested that manometers be added to the design for this purpose.

<u>Documents Provided:</u>

Each group will be provided

1. Electronic and printed copies of the Bistro design drawings
2. Copies of the control drawing packages for the B-150 HVAC lab at Laney, to be used as examples for content and format of the designs
3. Electronic copy of the KELE catalog for use in selecting I/O components and panel components
4. Access to the laptops in the classroom for using VISIO 2007 to develop the submittal drawings
5. Access to laptops in the classroom, and in the HVAC computer lab for use in researching control modules and control component specifications online.

Project Outcomes:

The control design package that each group will turn in should include about 4 sheets, containing the following information:

1. (Sheet 1) Title Sheet
2. (Sheet 2) System Schematic drawings, sequence of operations and logic diagram
3. (Sheet 3) Control module drawing with each input or output labeled, I/O table showing field installed components and control panel layout
4. (Sheet 4) Network Diagram and one suggestion for a GUI screen.

Make the document size 11 by 17 inches. The use of Visio is suggested.

Suggested Process:

It is suggested that you first review the drawings for both the Bistro dining area system and kitchen systems, since their operations are related and in some cases the areas of service overlap. Then start to develop the design for your assigned system in context of overall operations.

It is suggested that you prepare the information, e.g schematics, I/O tables, panel layouts etc. by hand (pencil) first and rework these drawings as needed until you are satisfied with their format. Then transfer/prepare the finished drawings in Visio.

Note that you are to provide all the things that are listed in the project outcomes section.

It is suggested that each group divide up the work among each group member. Every student MUST participate in this exercise. Part of the laboratory time on April 8th will be devoted to developing a project plan. The project plan for each group should include individual assignments and some deadlines for when things are to be completed. Each group has about 24 manhours of time allocated in the scheduled labs. It is expected that some additional time will be spent between labs.

Project Schedule:

March 18th – Visit the site, review drawings and submit questions
April 8th - Laboratory time allocated to practice with Visio, questions, group work
Groups develop and turn-in rough project plan
April 15th - Laboratory time allocated to for problem based group work
April 22th - Laboratory time allocated to for problem based group work
April 29th - Laboratory time allocated to for problem based group work
May 6th - Laboratory time allocated to for problem based group work
May 13th - **TURN IN DESIGNS; A CLASS DISCUSSION OF THE PROJECT**

Starting April 8th and after, 5 consecutive weeks of laboratory time will be allocated for group work in completing this exercise.

INSTRUCTOR ACCESS:
Outside of scheduled hours in class/laboratory, email me with questions or issues:
hhartshorn@peralta.edu

Assessment

Methods

- Classroom participation & attendance
- Homework – pre-lab completion prior to class
- Course exams (2, mid-term & the final exam)
- Evaluation of laboratory participation
- Evaluation of (8) laboratory reports
- Student team presentations (2 during the semester) – presenting their project findings
- Course project (1 assigned at mid-term) – turned in prior to student team presentations at the end of the term

Sample test questions

From the first midterm examination:

1. Which information will you need from an air handling duct to determine the airflow?

   a. fan speed and static pressure
   b. average air velocity and duct cross sectional area
   c. static pressure and duct diameter
   d. overall duct length and total pressure

2. What is the formula for calculating air volume?

a. duct area X volume (A x Q)
b. static pressure / velocity pressure (SP / VP)
c. duct area X air velocity (A x V)
d. total pressure - velocity pressure (TP - VP)

3. You take measurements of airflow in a round duct. The duct is 16 inches in diameter. What is the cross sectional **area** of the duct in square feet?

____________ s.f.

4. What primary measurements are simultaneously taken with a Pitot tube?

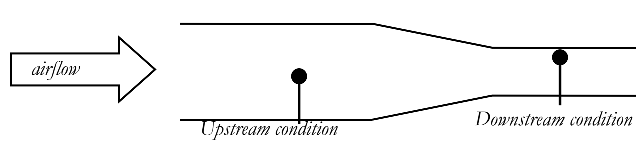
a. fan rpm and air velocity
b. duct size and static pressure
c. total air pressure and static pressure
d. flow direction and turbulence

5. With a suitable manometer, which attachment(s) would you use to measure coil pressure drop, which is the pressure difference between the air on the entering side and air leaving a coil?

a. static pressure tip
b. pitot tube
c. diffuser velocity
d. anemometer

6. If the cross sectional area of a duct decreases and there is no branch fitting at that point, which of the following statements would describe conditions just after the transition (e.g how is the downstream condition different from the upstream condition)?

a. The velocity pressure would decrease
b. The static pressure would increase
c. The velocity pressure would increase
d. The total pressure would increase



7. A device that uses a rotating propeller to determine air speed is an example of:

   a. anemometer
   b. balometer
   c. ammeter
   d. manometer

8. Typically where would the Total Pressure in an air handling system increase?

   ____

Adaptability to on-line format

This course is heavily based on laboratory work, testing and measurement and is less compatible with distance learning delivery.

Appendix A – Sample syllabus

LANEY COLLEGE
TESTING, ADJUSTING AND BALANCING
Environmental Controls Technology
Spring Semester - 2016

Course: Testing Adjusting and Balancing HVAC Systems

Course Number/code: ECT 212, Class 24330/24331

Time: Thursdays, Lecture 7:00 PM – 8:20 PM, Lab 8:30 PM – 10:00 PM

Instructor: Hadley Hartshorn (*hhartshorn@peralta.edu*)
Office hours: 6:50 – 7:00 pm, Thursdays in B151

Office: B151 **Units:** 2 units.

Phone: (510) 464-3292

Course Description:

Introduction to the theory and practice necessary to properly test, adjust and balance HVAC systems including air and water sub-systems. Develop proficiency in the use of instruments used to measure and adjust the flow of air and water.

Outcomes:

1. Demonstrate the ability to measure system airflow using anemometers, balometers, manometers, pitot tubes, tachometers and velometers.
3. Demonstrate the ability to measure and control system water flows using circuit setters, flowmeters and pump curves.
4. Demonstrate the ability to prepare typical balancing documents and compile a system balance report.
5. Demonstrate the ability to provide data appropriate for setup, commissioning and/or diagnosis of VAV terminal units.

Prerequisites: ECT 22 – Commercial HVAC Systems (co-requisite)

Text: *HVAC Testing, Adjusting, and Balancing Manual,* 3rd Edition, by John Gladstone and W. Bevirt, sponsored by the National Environmental Balancing Bureau, McGraw Hill - Publisher

Supplies Needed: calculator, graph paper, lab notebook

Recommended Tools: screwdriver(s), common lab hand tools

Topics:

Week	Date	Section	Chapter	Unit Description
1	1/28	Lecture	handouts	Review of HVAC Systems, Systems Video
		Lab	25	Math for TAB, Laboratory Tour, Safety Review
2	2/4	Lecture	2,6	Airflow Measurement, System Pressure Losses
		Lab	7, Lab 1	Airflow in Ducts - Duct Traverse and Pressure
3	2/11	Lecture	2, 4	Fan and System Curves
		Lab	7, Lab 2	TAB at Air Outlets - Balometer/Register Measurements
4	2/18	Lecture	3, 5	Fan Drives and Equations
		Lab	7, Lab 3A	TAB at Fans/Coils-Tachometer, Manometer, Anemometer
5	2/25	Lecture	18	Recording TAB Data
		Lab	Lab 3B	Air System Documentation
6	3/3	Lecture Lab	2-6, 18	***MID-TERM ASSESSMENT 1***
7	3/10	Lecture	17	Flow Measurements of Hydronic Systems
		Lab	8, Lab 4	Circuit Setters
8	3/17	Lecture	16	Pumps and Hydronic Equations
		Lab	8, Lab 5	Ultrasonic Flow Meter Use
9	3/24	Lecture Lab	-	***SPRING RECESS***
10	3/31	Lecture Lab	-	***HOLIDAY (C. Chavez)***
11	4/7	Lecture	15	Pumps and System Curves
		Lab	8, Lab 6	Pump Curve Drawing
12	4/14	Lecture	18	Recording Hydronic Data – ***Problem Based Exercise Intro***
		Lab	-	PB Exercise time
13	4/21	Lecture Lab	15-18	***MID-TERM ASSESSMENT 2***
14	4/28	Lecture	11	Heat Transfer
		Lab	Lab 7	Air-Water Heat Balance – PB Exercise Time
15	5/5	Lecture	handout	VAV Terminal Basics
		Lab/Lec	Lab 8	VAV Measurements – PB Exercise Time
16	5/12	Lecture	-	***Problem Based Project Presentations***
		Lab	chap 19	Electrical Measurements – Electrical Safety
17	5/19	Lecture	2-6,11,15-19	Course Review – Systems Documentation
		Lab	-	Review and Lab Wrap-Up
18	5/26	Lecture Lab	2-6,11,15-19	***FINAL EXAM***

Evaluation: Grades for the class will be assigned in accordance with the number of points earned for various class activities. The maximum number of points for each activity will be assigned as indicated below.

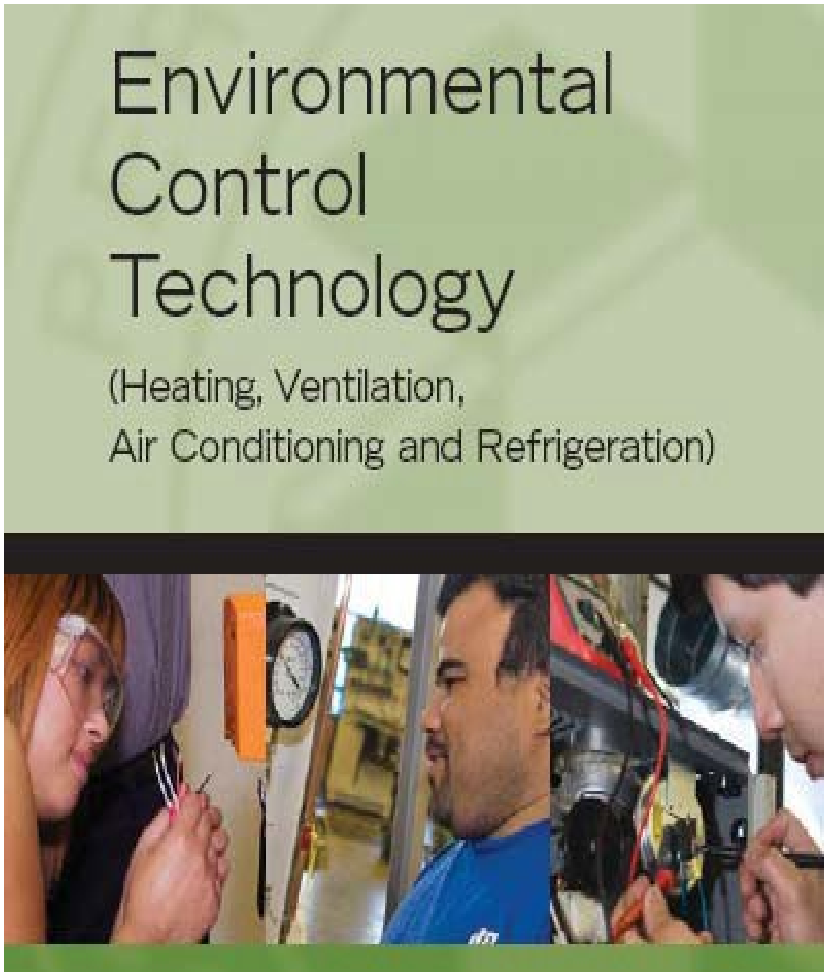
1.	Class Attendance and Participation	20 points
2.	Midterm Assessment #1	10 points
3.	Midterm Assessment #2	10 points
4.	Lab Exercises	20 points
5.	Problem Based Group Exercise	15 points
6.	Final Exam	25 points
	Total:	**100 points**

Note: When taking a test, the instructor will always be available to answer questions about the test and will clarify the questions as needed. If you have a question about the test, you must ask (only) the instructor. You must not copy answers or otherwise communicate with your classmates during any of the tests. Copying answers or asking for help from your classmates during a test is not allowed and is considered cheating. If you get caught cheating, you will receive an F or be expelled from the college.

Safety: Students are expected to obey safety practices typical for a classroom and laboratory environment.

Attendance: Students may be dropped from the course if the number of absences exceeds four weeks' worth of class meetings. However, extenuating circumstances may warrant consideration.

Appendix B – Problem Based Learning Scenario



LANEY COLLEGE: Problem Based Learning (PBL) Scenario
ECT 212 - Testing, Adjusting, and Balancing (TAB)

Guide developed by Kimiko Sakuma, Curriculum Consultant, 2012

Disclaimer: This material is based upon work supported by the National Science Foundation under Grant No. 0802595. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation

PROBLEM BASED LEARNING (PBL) SCENARIO

Instructor: Hadley Hartshorn
Course: Testing, Adjusting, and Balancing (TAB)
Course Number/Code: ECT 212

SCENARIO TITLE

"Determine the Performance of the Air Conditioning System"

Key Course Concepts:

- Demonstrate the ability to measure the air conditioning system airflow and correctly complete sample Testing, Adjusting and Balancing forms.
- Profile airflow in an entire building by measuring flow in an appropriately small sample of rooms.

SCENARIO DURATION

- **5 partial class periods**: An introduction to the Problem Based Learning (PBL) process, presentation of sample projects, and class time to work on the project as a group

BUSINESS PARTNER

Laney College, Environmental Control Technology (ECT)

LEARNING OBJECTIVES

By the end of the semester, students will be able to demonstrate the ability to:

- Demonstrate the ability to measure and adjust system airflow using velometers, balometers and pitot tubes
- Demonstrate the ability to review measurement data and correctly complete sample TAB forms

THE FOCUS OF THE PROBLEM

The focus of this Problem Based Learning (PBL) scenario is based around a real life scenario.

In various settings, the Problem Based Learning (PBL) scenario may be presented as a real time problem, hands-on scenario, or hypothetical problem. Using critical thinking and investigation, the students go through a process to solve a problem and provide recommendations for a solution.

PROBLEMATIC SITUATION

The Building "B" complex at Laney College was built in the early 1970s as part of original construction of the campus. There have been student and staff complaints ranging from uneven and fluctuating temperatures to not enough outside air being circulated within the building. The cause of the air conditioning concerns has not been determined. Some "spot" measurements have been taken and it is believed that the airflow in the complex is far off specification.

Your team has been subcontracted to measure the existing airflow in the building and make up a representative air balance report to determine the performance of the air conditioning system. As a team, it is your job to figure out how to measure the system airflow and correctly complete the sample Testing, Adjusting and Balancing forms. Your data will be used to determine possible ways to remediate the problems.

There will not be enough time to measure every air outlet in the complex. The challenge in this exercise is to select the right percentage of the total system to measure, and then use that information to project the performance of the entire complex. Your team will have to determine the schedule and time needed to take measurements. It is your job to create a report to convince the building owner/operator that the sample measurements that are taken are representative of the entire building.

Questions to think about while investigating the Problem Based Learning (PBL) scenario:

WHO *is involved?*

WHAT *is not working?*

WHEN *did the problem start?*

WHERE *is this scenario taking place?*

TIME *pressures or deadlines?*

STUDENT MATERIALS

The instructor will provide students with the following information:

- A copy of the Problem Based Learning (PBL) cycle and steps
- An explanation of the Problem Based Learning (PBL) approach
- Sample Testing, Adjusting and Balancing forms
- Design blueprints of building and the AC systems
- Tool: "Need to Know" to gather information
- Tool: Scoring rubric for final presentation
- Problem Based Learning (PBL) scenario evaluations: Team evaluation and online survey

Resources and Media:

- The internet
- Educational materials and books
- Configuration documents from the District Office

INSTRUCTOR ROLE

The instructor will support the Problem Based Learning (PBL) experience by:

- Introducing the scenario and process
- Facilitating reflection and discussion
- Providing applicable resources and materials
- Answering any questions related to the scenario and coursework
- Providing class time to work on the scenario

STUDENT ROLE AND GUIDELINES

Individual

The intended outcome will be measured by having each student:

- Distribute project tasks between the group members
- Perform a specific individual role in their team
- Perform a specific individual role in the final presentation
- Complete a Problem Based Learning (PBL) scenario and team evaluation as a part of the final project

Breakdown of Problem Based Learning (PBL) scenario tasks by class:

Class 1:Introduction
Date:________ • Introduction of the Problem Based Learning (PBL) approach and tools • The group will need to determine the decisions that need to be made, select the locations for the air measurements and develop the methods for substantiating that the sample is representative of the entire building • Collect and review the existing configuration documents for the building
Class 2: Develop the Plan
Date:________ • Create the group "Project Plan": Timeline of how to achieve solution and task assignments for each person on the team • Present "Project Plan" to the class • Refine the project plan from the class discussion and prepare for implementation of the plan
Class 3: Take Measurements
Date:________ • The group will start to take the measurements and analyze the gathered information based on a review of the initial measurements, assess the adequacy of the plan and schedule other/additional measurements as needed
Class 4-5: Finish Measurements and Document the Solution
Date:________ • The group will finish taking measurements and start the process of organizing the design documentation and presentation materials
Class 6: Present the Solution
Date:________ • The group will present the final documentation and recommended solution(s) • The class will discuss the solution and insights *Extra credit will be giving to presentations provided in Power Point

STUDENT ROLE AND GUIDELINES

Group

The intended group outcome will be measured by providing:

- A group presentation where each student will individually present a particular segment (1-2 minutes) of the recommendations to the client
- A single document which describes recommendations on the problem and the solution(s)
- A class discussion where each student on the team will make an oral presentation of what they learned

Group Size:

- 4 or 5 groups (Approximately 5-6 students per group)
- The Instructor will participate in the selection of members of each group

Presentation Guidelines:

Problem Based Scenario is 20 points out of 100:

- The project must be completed and final reports must be turned in on or before the day of the presentation which is **Thursday, May 5, 2011**
- The project grade will be equivalent to a Midterm, a maximum of 20 points, but extra credit will be given to presentations provided in Power Point.

Refer to the “Scoring Rubric for Final Presentation” tool for the key elements of how the final presentation will be graded. Final Presentation is worth 5 out of 20 points.

STUDENT FEEDBACK

As a team, and individually - students will review, assess and provide feedback regarding the Problem Based Learning (PBL) scenario experience.

Requirements of the final project: Before final presentation

- Completion of team member evaluation and online survey

TEAM LINK

The instructor will support the team learning process by allowing:

- 15-20 minutes approximately every week, where students will be able to work on the scenario as a group
- Time to meet during class, outside of class and on the phone to work on the scenario

BEST Center Curricula, Resources & Recordings

Academic Programs
Georgia Piedmont Technical College - Building Automation Systems
Milwaukee Area Technical College - Sustainable Facilities Operations
Laney College - Commercial HVAC Systems
City College San Francisco - Commercial Building Energy Analysis & Audits

Professional Development Materials, Presentations & Videos
National Institutes
Building Automation Systems Instructor Workshops
Webinars (e.g., BEST Talks)

Faculty Profile Videos
Reports & Case Studies
Marketing Resources