FINAL REPORT

Lighting Analysis of Engineering 2 Rooms 1303A and 1303B

A study of the present lighting system and the development of a more optimal method of lighting for the University of Waterloo, Engineering 2 rooms 1303A and 1303B, in economic and ergonomic terms.

Group Members:	Christine Burke	88089176
	Khin Kyone	88099970
	Sophia Lee	88004226

Supervisor: Professor Chandrashekar

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1.0 Introduction

Lighting plays an extremely important role on the University of Waterloo's campus. Many factors must be taken into account when performing an analysis of a lighting system such as environmental, economic, and ergonomic factors. The potential economic savings provide an incentive for initiating a review of the current system besides the obvious environmental benefits which could be derived from energy conservation. In general, improved lighting efficiency would greatly benefit the university in many different ways.

2.0 Problem Statement

Classrooms are used for many purposes outside of regular lecture hours; individual studying, group work, and group meetings. Electricity is wasted when the lights are on and no one is using the room, when there is insufficient distribution of control of light sources, and when students study by themselves in large rooms with all the lights on, using much more light than is needed for the task. The main systems design classrooms used for lectures are 1303A (presently the 3B room) and 1303B (presently the 2A room). For this reason, the workshop was limited to the study of these two rooms. Alternative lighting types and configurations were suggested and analyzed in terms of economics, ergonomics, and feasibility.

3.0 Methods

Room usage for 1303A and 1303B was recorded for weekdays after class hours and for weekends. The number of students in a room was recorded each hour and if the room was not in use, it was noted whether or not the lights were on or off to indicate wasted electricity. Each

room was analyzed separately since it was necessary to compare usages of individual rooms. Assumptions made while conducting the study (refer to Appendix C for the data of the study):

i) Students that were accounted for stayed in the room for the entire hour.

ii) If the rooms were empty at the time of the reading, they were empty for the entire hour.

iii) Off-classroom hours are from 5pm-8am inclusive.

iv) The lights were off between 2am and 8am if the last recording shows the lights to be off and no one is able to record otherwise.

v) Weekends are defined as Saturday and Sunday.

4.0 Resources

There were many people who were involved from the start of the term who were helpful in guiding us throughout the analysis stage of the study. Patti Cook, who is in charge of waste management at the University of Waterloo, directed us to Horst Beyerle of Plant Operations. Mr. Beyerle supplied us with the cost of energy on campus, as well as energy conservation plans that have been on-going at the University of Waterloo. We used the information he supplied to us as a basis for the feasibility studies of our suggestions, and our proposal to improve the lighting on campus. As well, Professor Chandrashekar directed us to Professor Adrian, who is a member of the Optometry faculty and specializes in lighting. We discussed general classroom lighting with him. Professor Adrian was able to supply us with a broad background about fluorescent lighting as well as information on different lighting configurations. Ron Gibbons, his graduate student who also works as a lighting engineer consultant, provided us with details on reflectors.

5.0 Overview of Activity Schedule

January: The first month was spent analyzing and redefining the problem. We discussed the purpose and scope of our workshop with several people and through these discussions, we were able to narrow our problem to one which we felt we could investigate in the allotted time.

February: The second month was spent conducting a study of room usage of 1303A and 1303B. We attempted to get information for all days of the week, thus allowing us to analyze the data according to weekend usage and weekday usage. As well, light readings were taken of both rooms to determine the lighting levels. During this month, we also gathered information which we needed for financial calculations. This stage consisted of communicating with people involved in energy conservation at the university.

March: The last month was spent analyzing the data collected from the study, generating possible solutions to the problem, and recommending the most promising one. This part of the process involved deciding on the approach of analyzing the data, how to interpret the data, and how we could use it to quantify the possible solutions. As well, the solutions and our proposal was presented to the WATGREEN group on April 1.

6.0 Task Assignment for Group Members

All group members were involved with the study, contacting people for information, and generating possible solutions. However, once this was done, the possible solutions were divided

up amongst the group members and analyzed according to cost and feasibility. This stage was performed considering just 1303A and 1303B, and then extrapolated for the entire campus. All members decided on the most promising combination of solutions to the problem.

7.0 Possible Solutions to the Problem

Please refer to Appendix A which lists the possible solutions along with cost, potential savings, and payback period. Please note that inflation and increase in cost of electricity were not taken into account when calculating the payback period. Refer to Appendix B for the calculations associated with each suggestion. General assumptions are (courtesy of Horst Beyerle, Plant Operations):

i) The cost of electricity is 6.5 cents/kwh and is constant.

ii) The cost of a fluorescent lightbulb is $1.67 each.

iii) A university school year is 323 days or 46 weeks. This is assumed because the last two weeks of every term (three terms in a year) there are no classes and no examinations.

iv) The cost of labour is $25/hr.

v) The average number of off-class hours that lights are on in a room is seven. This was tabulated from the data collected from the study.

vi) The average number of hours that a room is used on the weekend with the lights on is 25 hr/weekend. This was tabulated from the data collected from the study.

Assumptions associated with each suggestion are listed below.

1. **Locking all classrooms**

   Locking all classrooms after hours would eliminate the problem of a room with the lights on not being used. It would require no added cost to the university. The drawback to this suggestion is that students would not have enough places to study or conduct group meetings.

   Assumptions made:

   i) There are 163 lecture rooms on campus.

   ii) Each lecture room on campus contains 84 working lights.

   iii) The labour is readily available to lock/unlock the rooms (maintenance staff).

2. **Locking some of the classrooms**

   Locking half of the classrooms on campus would still allow students to have access to some rooms in which they wish to work. It would encourage students to share rooms with other students therefore decreasing the occurrence of one student/classroom with all the lights on.

   Assumptions made: These are same as the above suggestion.

3. **Adding new lights**

   Adding new lights to the back of the classroom would enable students to take notes during overhead teaching and films. Although this suggestion may be appropriate for other departments which show films often, it is not practical for systems design since

lectures rarely include films as part of the normal curriculum. As well, overheads can be seen without any difficulty with all the lights on. This suggestion has been eliminated as an improvement over the current lighting.

4. Reflectors

Proper reflecting of available light reduces the number of the lights required in a room. This would result in a more evenly lit room.

Assumptions made:

i) Reflectors make lights twice as efficient which allow the removal of half the lights (Ron Gibbons).

ii) All the lights are on for 16 hr/day.

iii) Forty-two fixtures are installed in each room and all fixtures will contain one light bulb.

iv) Two fixtures/hr can be installed. For any given room, this means labour is 21 hrs * 2 people = 42 hours.

v) A light bulb is replaced once every two years and takes only ten minutes to replace.

5. Sectional lighting

Sectional lighting requires different light switches for different lights in a classroom. This would allow the option of minimal lighting during projection teaching or films which allows the student to take notes. As well, this would decrease the number of lights

a student would use when studying in the room during off-class hours since only a portion of the lights are required.

Assumptions made:

i) Each room has three switches which control three sections of the room.

ii) Each section contains 28 lights.

iii) Students who use the room to study only use one section.

iv) Labour involved is 8 hrs * 2 people = 16 hours total.

6. Re-distributing lights

There is insufficient lighting in 1303B according to the light meter readings (refer to Appendix A). The recommended amount of lux for general lighting is between 500 and 1000 lux (Stones, Illene. Lighting Ergonomics, Canadian Centre for Occupational Health and Safety, Hamilton, Ontario, 1989, p.5). The light meter reading for 1303B indicates an average of 312 lux for the entire room. As well, the room is not evenly lit which means that certain areas of the room are considerably less than 312 lux. The fact that 1303B has a much lower illumination level can be attributed to the lack of lighting fixtures in the room. In 1303A, seventy-four (74) fluorescent lights are in place in pairs, but there are only thirty-one (31) singly placed fluorescent lights in 1303B.

The solution to this problem does not involve any cost except for labour. Fluorescent lights can be taken from the side blackboard in 1303A (which are not used) and from the fourth year study room. The fourth year study room is considerably smaller and has 39

lights (compared to 31 in 1303B).

7. Motion Detectors

Motion detectors would eliminate the possibility of the lights being on with no one in the room. However, this does not solve the problem of a student using a room by himself/herself with all the lights on.

Assumptions made:

i) There are 2 hr/weekday of electricity wasted (ie. lights are left on).

ii) There are 8 hr/weekend of electricity wasted.

iii) The cost of a motion detector is $150 for a classroom.

iv) It takes eight hours and two people (total: 16 hours) to install a motion detector in a classroom.

v) The university will take full advantage of the incentive offered by Ontario Hydro for motion detectors. This is a $35 rebate for each motion detector.

vi) A classroom requires only one motion detector.

8. Dimmer Switches

This would require an entire reconfiguration and rewiring of the classroom and would only be a benefit for slide show presentations/films where students wish to take notes. As mentioned previously, this is not practical for systems design lectures. Therefore, this suggestion is not feasible.

9. Scheduling of classes according to class size

This recommendation involves scheduling smaller classes in smaller rooms to free up the larger classrooms during the day for other activities by the students who do not have class. Systems design has control over seven classrooms and can schedule the smaller classes (less than ten students) in the smaller lecture rooms. There is no cost to this and would allow students to have a larger place to study when they are waiting for their next class to begin which they can share with other students. This term (winter 1991) there are two courses of less than ten people using 1303A.

10. Permanent signs informing people to turn the lights off

Often, students do not think about turning off the lights when they are about to leave the room. Signs placed by the door or near the light switches would remind them to do so, thus reducing the occurrence of the lights on with no one in the room. The signs would be made permanent so that they would not be destroyed or taken down.

Instead of signs, stickers could be affixed near the light switches. Ontario Hydro provides stickers, and possibly the university could obtain a number of them free of charge. These could be placed in classrooms, washrooms, and hallways as a reminder to students to conserve energy.

Assumptions made:

i) It takes 1 hour of labour to make the sign and affix it to the wall.

ii) Stickers are obtained from Ontario Hydro for no fee.

11. Automatic light switches

Timers could be used to control turning off the classroom lights. Lights would automatically be turned off at 5pm and continuously turned off every hour afterwards. At this point, students studying in a room would have to manually turn on the lights. This would reduce the occurrence of the lights on while the room is empty. However, this alternative is hard to implement in older buildings because it requires a lot of labour to switch over to automatic monitoring.

Assumptions made:

i) There are 2 hr/weekday of electricity wasted (ie. lights are left on).

ii) There are 8 hr/weekend of electricity wasted.

8.0 Outcomes of the Project

8.1 Proposal

The following is a proposal of reconfiguring the lights in 1303A and 1303B which involves a combination of suggestions mentioned earlier: sectional lights, motion detectors, and signs.

Sectional lighting solves most of the issues that were indicated in the problem statement. It reduces the usage of light when there are only a few students in the room which wastes less electricity if the lights are left on and allows the option of turning off a portion of the lights during films/slide shows. Implementing sectional lighting only requires rewiring and the addition of light switches which is minimal when compared to other suggestions. At the same time the work is being done to incorporate sectional lighting, a motion detector can be installed in one section so that only that section turns on when someone enters a room. This discourages students who wish to use the room for studying from turning on all the lights since a portion of the lights turn on automatically when they enter. Lastly, signs should be posted by the light switches to remind students to turn all lights off when they finish using the room.

The cost of this proposal is similar to the costs for each suggestion as outlined in Appendix B. However, if the room was switched to sectional lighting and a motion detector added at the same time, it is felt that it would take less time than if done separately. The new cost is outlined below:

Cost:

Materials:
$ 20 - signs
150 - motion detector
50 - materials for sectional lighting

$ 220 - Total Cost of Materials

Labour:
1 hr - to make and affix sign
24 hrs - sectional lighting and install motion detector (12 hours times two people)
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25 hrs - Total time for labour

Cost of Labour = 25 hours * $ 25/hr = $ 625

Tot. Cost of Proposal = **Cost of Materials + Cost of Labour**
= **$ (220 + 625)/classroom**
= **$ 845/classroom**

Savings:

The savings are the amount from unused electricity and from sectional lighting.

Total Savings = **$ (153 + 341)**
= **$ 494/year**

Payback Period:

Payback = **$ (845/494) = (approximately) 1.7 years**

9.0 Achievements

During this workshop, we have managed to provide a proposal which will reduce the problem of wasted electricity, insufficient control of light, and improve the atmosphere for students. As well, we have succeeded in providing a comprehensive list of solutions along with the costs

involved. Since no actual documentation has existed previously, we feel that this is a major achievement that will benefit the university.

10.0 Disappointments

In our discussions with Plant Operations, we found that little documentation was available regarding lighting improvements completed on campus over the last several years. This caused a delay in receiving the information we needed for some of our calculations. As well, it was hard to quantify some of our suggestions, since the required information could not be easily obtained from Plant Operations. We were forced to make assumptions that we felt were not totally indicative of real life situations, such as holding the cost of electricity constant over the payback years, as well as assuming that the dollar value does not change over time. Also, we extrapolated from our calculations to apply them to the entire campus. We had to assume that E2 1303 A and B represented a typical classroom on campus, in terms of size, student use, and electrical consumption. We felt that this was not an accurate representation of the campus, but this assumption allowed us to determine very rough dollar values for our alternatives and thus provide an estimate of the potential savings.

11.0 Possible Improvements to the Workshop Methodology

Areas that we feel we could have improved on:

i) Used better data collecting methods such as automatic monitoring of lights.

ii) Started the data collection earlier.

iii) Used future electricity costs and dollar values when we calculated payback periods.

iv) Looked more closely at the electrical components of our suggestions, for example, different types of lights.

12.0 Conclusions

Although many changes have already been made to improve energy consumption on campus, there are still improvements that could be made with regards to lighting. The proposal that was recommended in this document offers the most feasible alternative to the system that is currently in place. The payback period indicates that this redesign is relatively inexpensive to implement. Also, the changes required are neither difficult or extensive.

13.0 Acknowledgements

We would like to thank the following people for their cooperation and knowledge during the duration of this workshop (in alphabetical order):

Professor Adrian	- optometry professor
Horst Beyerle	- Plant Operations
Professor Chandrashekar	- systems design chairman and professor
Patti Cook	- waste management
Ron Gibbons	- systems graduate and lighting engineer
Professor Hahn	- systems design professor
Professor Kay	- environmental studies professor
Karen Ledrew	- registrar's office

and our classmates who helped us in monitoring the usage of rooms.

14.0 Suggestions for Future Workshops

During our study we found many aspects other than classrooms where savings can be made. Future workshops can examine the following:

1. The feasibility of implementing motion detectors in offices (particularly systems design offices). There are 61 offices in systems design alone, and many of the professors leave their lights on when they go to lecture a class. A survey could be done to see the average amount of time an office is empty with the lights left on. Since Ontario Hydro offers incentive packages for motion detectors, the cost of implementing them in offices would be relatively inexpensive.
2. Currently, most computers in computer rooms are left on 24 hours a day. According to Plant Operations, a computer consumes about 150 watts. It is not necessary for the computers in 1302, 1308, and EL108 to be left on after a user is finished his/her task. A study could be conducted determining ways to encourage students to turn computers off after use. Obvious suggestions are to incorporate reminders in the logon/logoff procedure of the computer and to post signs.
3. Education is the first step to reducing energy consumption. A workshop could look at ways of educating people on this subject.

Appendix A:

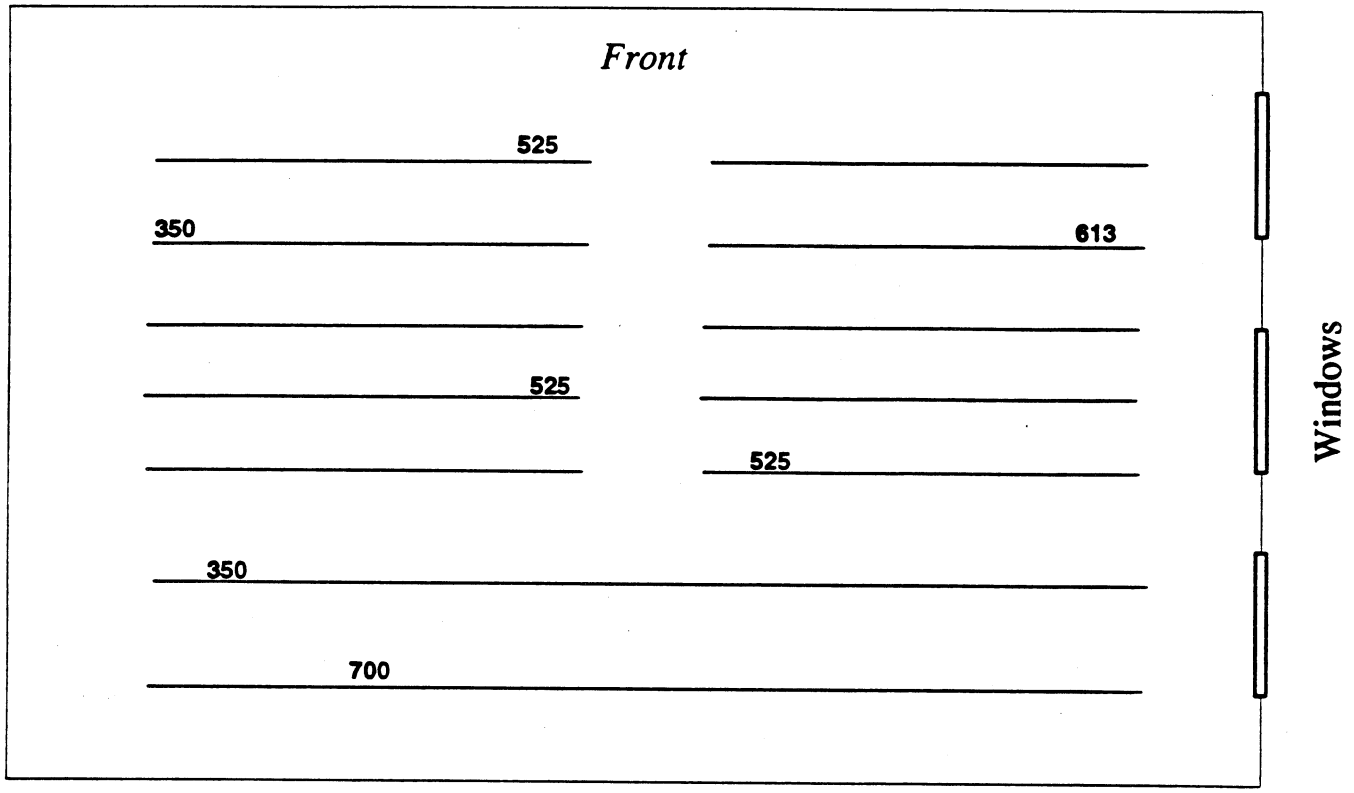
Summary of Costs/Savings for Suggestions

Light Meter Readings for 1303A and 1303B

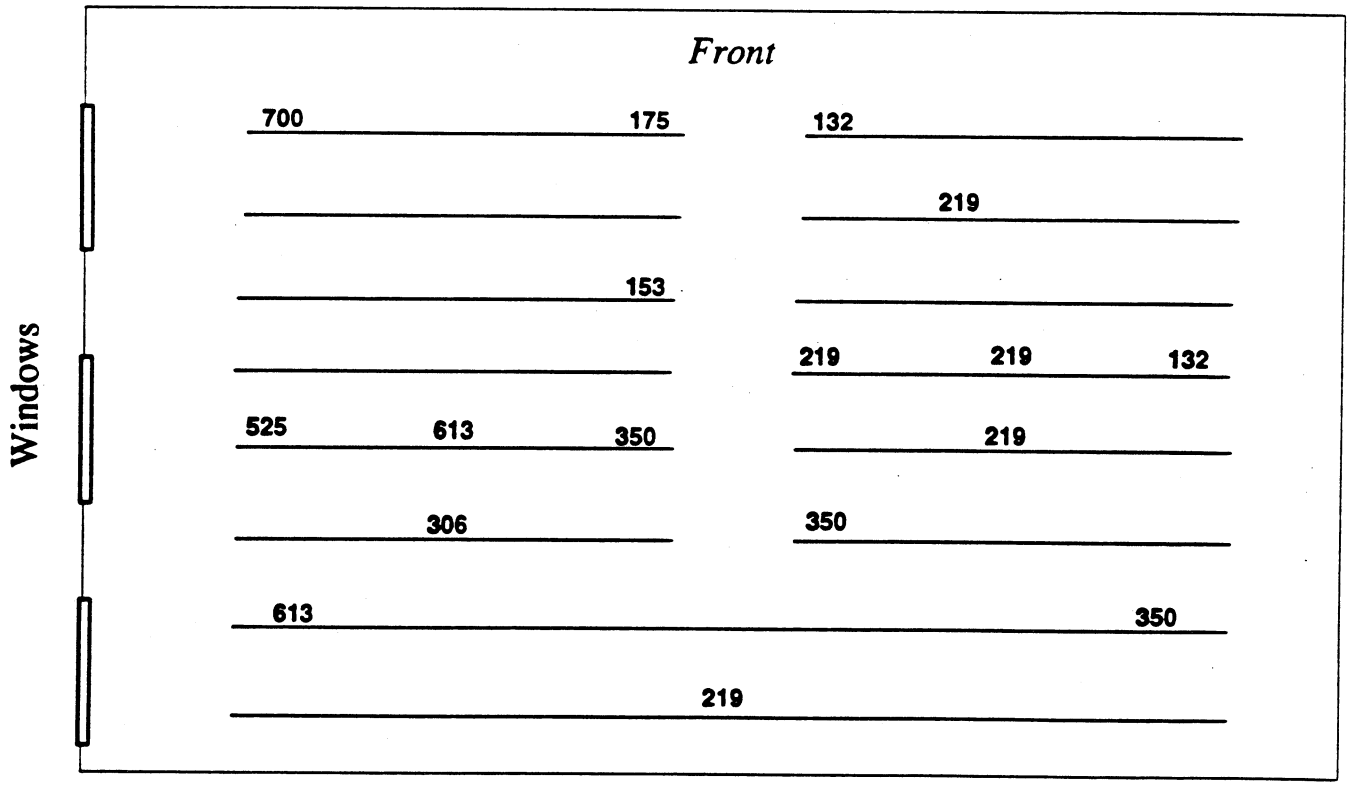
Suggestion	Cost ($) (for a class)	Cost ($) (for campus)	Savings ($) (for a class)	Savings ($) (for campus)	Payback (yrs) (for a class)	Payback (yrs) (for campus)
Lock all rooms	0	0	317	51671	immediate	immediate
Lock half the rooms	0	0	158.5	25836	immediate	immediate
Reflectors	2100 + 1050	342300 + 171150	1391	226733	2.2	2.2
Sectional Lighting	50 + 400	8150 + 65200	341	55583	1.3	1.3
Motion Detectors	150 + 400	24450 + 65200	154	25102	3.6	3.6
Scheduling classes	0	0	n/a	n/a	n/a	n/a
Permanent Signs	20 + 25	3260 + 4075	154	25102	3.5 months	3.5 months
Automatic Switches	undetermined	undetermined	154	25102	undetermined	undetermined
Proposal	220 + 625	35860 + 101875	494	80522	1.7	1.7

* Please note that costs have been broken down into material and labour costs respectively.

Light Meter Readings (luxes): 4:00PM

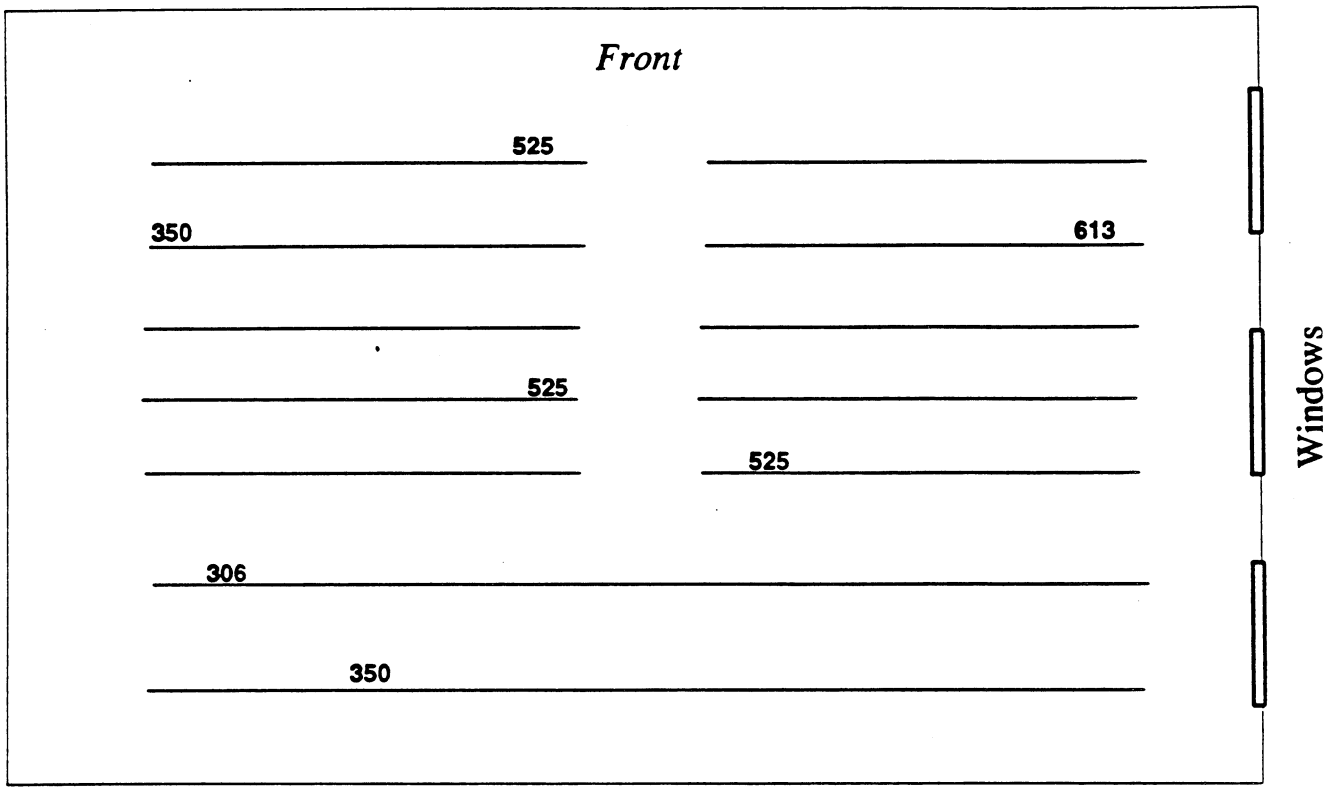


Engineering 2, Room 1303A

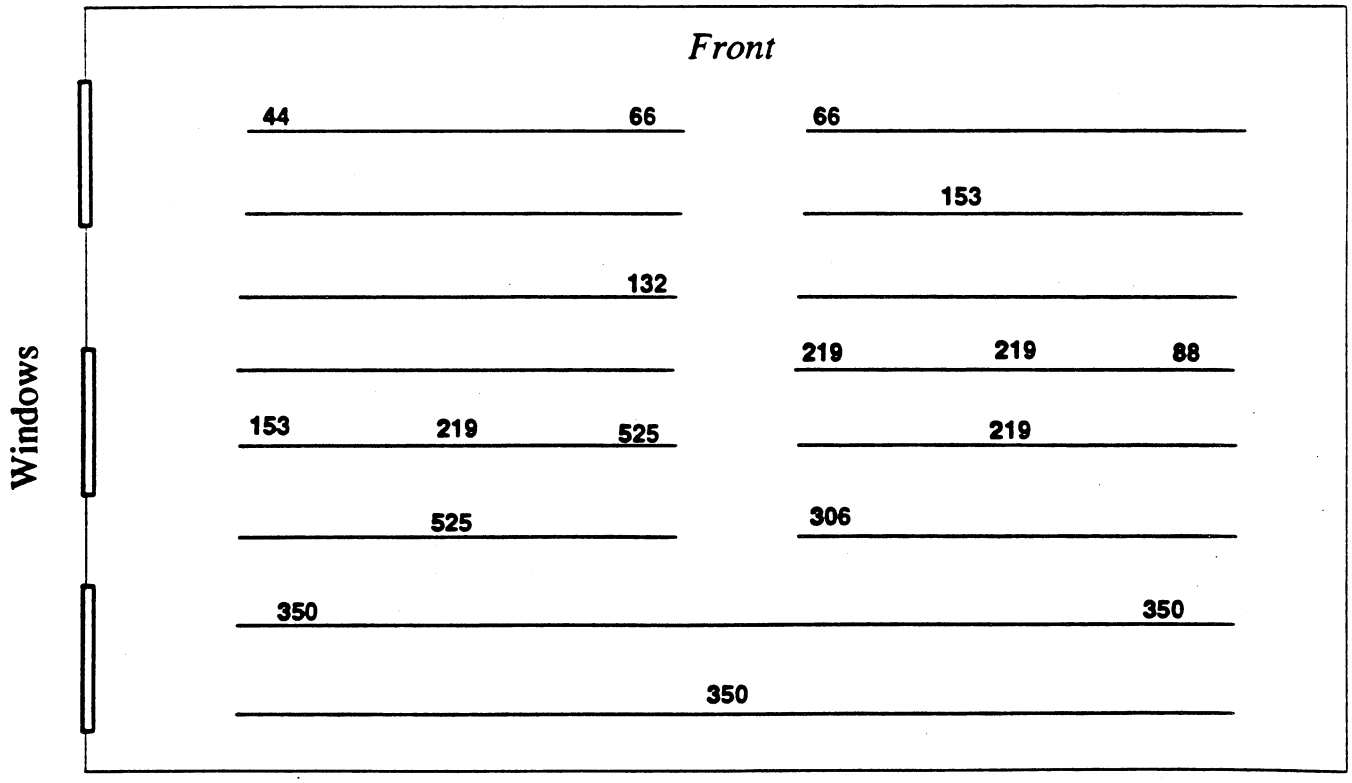


Engineering 2, Room 1303B

Light Meter Readings (luxes): 8:30PM



Engineering 2, Room 1303A



Engineering 2, Room 1303B

Appendix B:

Calculations Associated with Suggestions

1. Lock all classrooms

Costs

None

Savings

i) Average cost/weekday for a room: (1.11(1303A) + 0.45(1303B)) / 2 = $ 0.78
This the average of the average cost for the use of classroom 1303A and 1303B (calculated from our data)

ii) Average cost/weekend for a room: (4.04(1303A) + 1.94(1303B)) / 2 = $ 2.99

Total Savings (per year per classroom): **$317**

2. Lock some classrooms

Costs

None

Savings

Half of the previous suggestion

Total Savings (per year per classroom): **$159**

3. Reflectors

Costs

Material: $50/reflector * 42 fixtures = $2100/classroom
Labour: 21 hours * 2 people = 42 hours
42 hours * $25/hour = $1050/classroom

Total Costs (per classroom): **$3150**

Savings

i) 1 half of 84 lights = 42 lights * $1.67 = $70
ii) Energy consumption = 42 * $ 0.065 * 0.034 Watts = 0.09282/hour
= $1.49/day
= $481/year

iii) Lights permanently removed will not have to be replaced

For two years:$70(material) + $1750 (labour) = $1820
= $910/year

Total Savings (per year per classroom): **$1391**

4. Sectional Lighting

Costs

Material: $50
Labour: 8 hours * 2 people = 16 hours
$25 * 16 hours = $400/classroom

Total Costs (per classroom): **$450**

Savings

i) 56 lights will be off = 0.12376 cents/hour
for 5 days: 35 hours $4.33
for 1 weekend: 25 hours: +$3.09
= $7.42/week

Total Savings (per year per classroom): **$342**

5. Motion Detectors

Costs

Material: $150 per motion detector
Labour: 8 hours * 2 people = 16 hours
$25 * 16 hours = $400/classroom

Total Costs (per classroom): **$550**

Savings

i) Energy consumption = 18 hours * 84 lights * 0.034 kw * $0.065 = $3.34/week

Total Savings (per year per classroom): **$154**

6. Signs

Costs

Material: $20 (2 signs)
Labour: $25/hour

Total Costs (per classroom): **$45**

Savings

Same as for motion detectors

Total Savings (per year per classroom): **$154**

7. Automatic Light Switches

Costs

undetermined

Savings

i) Energy consumption = 84 lights * 0.034 Watts * $ 0.065 * 2 hours = $ 0.37128/day
ii) Energy consumption = 84 lights * 0.034 Watts * $ 0.065 * 8 hours = $ 1.48512/weekend

Total Savings (per year per classroom): **$154**

Proposal

Using sectional lighting in conjunction with motion detectors and signs.

Costs

Material:
$20 (sign)
$150 (motion detector)
+ $50 (sectional)
$ 220 (fixed costs)

Labour:
1 hour (sign)
+ 12 * 2 = 24 hours (motion detector & sectional lighting)
25 hours or $625

Total Costs (per classroom): **$845**

Savings

i) Amount wasted (if not using motion detectors) = $153/year
ii) 56 lights (if not using sectional lighting) = $341/year

Total Savings (per year per classroom): **$494**

Appendix C:

Data collected from study

Classroom Usage of Lighting

The following observations are of the clasrooms during non-class time.
Students are using the classerooms to meet, do projects and study.
The lights for the blackboard are not on during these times.

Assumptions:

1) Number of students in the room(s) occupy it for the entire hour as checks are done only once an hour.

2) The lights are off between 2am and 8am if the last recording is off and no one is able to record otherwise.

Data:

Bulb wattage (fluorescent): .034 kW

Price per Kilowatt hour: $ .065

Total number of working bulbs in 1303A: 80

Total number of working bulbs in 1303B: 37

Number of working bulbs for studying purposes in 1303A: 74

Number of working bulbs for studying purposes in 1303B: 31

Date: **22 Feb 92 Saturday**

Time	Amt of People in Room 1303A	Lights On/Off	Amt of People in Room 1303B	Lights On/Off
14	13	on	1	on
15	11	on	2	on
16	8	on	4	on
17	8	on	3	on
18	8	on	0	on
19	7	on	0	on
20	12	on	0	on
21	12	on	0	on
22	6	on	1	on
23	2	on	1	on
24	2	on	0	on
1	1	on	0	on
2	1	on	0	on
3	0	off	0	on
4	0	off	0	on
5	0	off	0	on
6	0	off	0	on

	1303A	1303B
Total hours of lights on:	13	17

Amount of hours with the lights on and no one in 1303A: 0

Amount of hours with the lights on and no one in 1303B: 11

Cost of Lighting = (cost/watt hour) * (bulb wattage) * (number of bulbs) * (hours)

Cost for 1303A: $ 2.12602
Cost for 1303B: $ 1.16467

Total cost: $ 3.29069

Amount wasted due to no one in 1303A with lights on: $ 0
Amount wasted due to no one in 1303B with lights on: $ .75361

Total amount wasted: $ .75361

Date: **23 Feb 92 Sunday**

Time	Amt of People in Room 1303A	Lights On/Off	Amt of People in Room 1303B	Lights On/Off
7	0	off	0	on
8	0	off	0	on
9	0	off	0	on
10	0	off	2	on
11	0	on	3	on
12	3	on	2	on
13	5	on	2	on
14	11	on	0	off
15	13	on	0	on
16	10	on	0	on
17	3	on	0	on
18	7	on	0	on
19	5	on	0	on
20	7	on	5	on
21	5	on	1	on
22	5	on	0	on
23	4	on	2	on
24	3	on	2	on
1	0	off	2	on
2	0	off	0	off
3	0	off	0	off
4	0	off	0	off
5	0	off	0	off
6	0	off	0	off

	1303A	1303B
Total hours of lights on:	14	19

Amount of hours with the lights on and no one in 1303A: 1
Amount of hours with the lights on and no one in 1303B: 10

Cost of Lighting = (cost/watt hour) * (bulb wattage) * (number of bulbs) * (hours)

Cost for 1303A: $ 2.28956
Cost for 1303B: $ 1.30169
Total cost: $ 3.59125

Amount wasted due to no one in 1303A with lights on: $.16354
Amount wasted due to no one in 1303B with lights on: $ .685
Total amount wasted: $.84864

Date: **24 Feb 92 Monday**

Time	Amt of People in Room 1303A	Lights On/Off	Amt of People in Room 1303B	Lights On/Off
17	4	on	0	on
18	4	on	0	on
19	2	on	0	on
20	2	on	0	on
21	0	on	0	on
22	0	on	0	on
23	0	off	0	off
24	0	off	0	off
1	0	off	0	off
2	0	off	0	off

	1303A	1303B
Total hours of lights on:	6	6

Amount of hours with the lights on and no one in 1303A: 2

Amount of hours with the lights on and no one in 1303B: 6

Cost of Lighting = (cost/watt hour) * (bulb wattage) * (number of bulbs) * (hours)

Cost for 1303A: $ .98124
Cost for 1303B: $ .41106

Total cost: $ 1.3923

Amount wasted due to no one in 1303A with lights on: $.32708

Amount wasted due to no one in 1303B with lights on: $.41106

Total amount wasted: $.73814

Date: **25 Feb 92 Tuesday**

Time	Amt of People in Room 1303A	Lights On/Off	Amt of People in Room 1303B	Lights On/Off
17	4	on	2	on
18	3	on	2	on
19	class	on	3	on
20	class	on	0	on
21	1/2 class	on	1/2 class	on
22	0	on	0	on
23	0	on	0	on
24	0	off	0	off
1	0	off	0	off
2	0	off	0	off

	1303A	1303B
Total hours of lights on:	7	7

Amount of hours with the lights on and no one in 1303A: 2

Amount of hours with the lights on and no one in 1303B: 3

Cost of Lighting = (cost/watt hour) * (bulb wattage) * (number of bulbs) * (hours)

Cost for 1303A: $ 1.14478
Cost for 1303B: $ .47957

Total cost: $ 1.62435

Amount wasted due to no one in 1303A with lights on: $.32708

Amount wasted due to no one in 1303B with lights on: $.20553

Total amount wasted: $.53261

Date: **26 Feb 92 Thursday**

Time	Amt of People in Room 1303A	Lights On/Off	Amt of People in Room 1303B	Lights On/Off
17	4	on	6	on
18	2	on	7	on
19	exam	on	exam	on
20	exam	on	exam	on
21	exam	on	exam	on
22	0	on	0	on
23	0	off	0	off
24	0	off	0	off
1	0	off	0	off
2	0	off	0	off

	1303A	1303B
Total hours of lights on:	6	6

Amount of hours with the lights on and no one in 1303A: 1

Amount of hours with the lights on and no one in 1303B: 1

Cost of Lighting = (cost/watt hour) * (bulb wattage) * (number of bulbs) * (hours)

Cost for 1303A: $ .98124
Cost for 1303B: $ .41106

Total cost: $ 1.3923

Amount wasted due to no one in 1303A with lights on: $.16354

Amount wasted due to no one in 1303B with lights on: $.06851

Total amount wasted: $.23205

Date: **29 Feb 92 Saturday**

Time	Amt of People in Room 1303A	Lights On/Off	Amt of People in Room 1303B	Lights On/Off
10	0	off	0	off
11	0	off	0	off
12	0	off	0	off
13	0	on	2	on
14	3	on	4	on
15	3	on	4	on
16	1	on	2	on
17	3	on	1	on
18	2	on	1	on
19	1	on	1	on
20	2	on	0	on
21	2	on	0	on
22	3	on	1	on
23	0	off	0	on
24	0	off	0	on
1	0	off	0	on
2	0	off	0	on
3	0	off	0	on
4	0	off	0	on
5	0	off	0	on
6	0	off	0	on

	1303A	1303B
Total hours of lights on:	10	18

Amount of hours with the lights on and no one in 1303A: 1
Amount of hours with the lights on and no one in 1303B: 10

Cost of Lighting = (cost/watt hour) * (bulb wattage) * (number of bulbs) * (hours)

Cost for 1303A: $ 1.6354
Cost for 1303B: $ 1.23318

Total cost: $ 2.86858

Amount wasted due to no one in 1303A with lights on: $.16354
Amount wasted due to no one in 1303B with lights on: $ .6851

Total amount wasted: $.84864

Date: **1 Mar 92 Sunday**

Time	Amt of People in Room 1303A	Lights On/Off	Amt of People in Room 1303B	Lights On/Off
7	0	off	0	on
8	0	off	0	on
9	0	off	0	on
10	2	on	0	on
11	3	on	1	on
12	2	on	1	on
13	7	on	3	on
14	6	on	3	on
15	4	on	3	on
16	0	on	5	on
17	2	on	4	on
18	2	on	0	on
19	1	on	1	on
20	3	on	2	on
21	1	on	2	on
22	3	on	2	on
23	3	on	0	on
24	0	off	0	off
1	0	off	0	off
2	0	off	0	off
3	0	off	0	off
4	0	off	0	off
5	0	off	0	off
6	0	off	0	off

	1303A	1303B
Total hours of lights on:	14	17

Amount of hours with the lights on and no one in 1303A: 1
Amount of hours with the lights on and no one in 1303B: 6

Cost of Lighting = (cost/watt hour) * (bulb wattage) * (number of bulbs) * (hours)

Cost for 1303A: $ 2.28956
Cost for 1303B: $ 1.16467
Total cost: $ 3.45423

Amount wasted due to no one in 1303A with lights on: $.16354
Amount wasted due to no one in 1303B with lights on: $.41106
Total amount wasted: $ .5746

Date: **7 Mar 92 Saturday**

Time	Amt of People in Room 1303A	Lights On/Off	Amt of People in Room 1303B	Lights On/Off
10	1	on	1	on
11	1	on	0	on
12	1	on	0	on
13	2	on	1	on
14	7	on	2	on
15	4	on	2	on
16	0	on	0	off
17	3	on	0	off
18	3	on	0	off
19	2	on	2	on

	1303A	1303B
Total hours of lights on:	10	7

Amount of hours with the lights on and no one in 1303A: 1

Amount of hours with the lights on and no one in 1303B: 2

Cost of Lighting = (cost/watt hour) * (bulb wattage) * (number of bulbs) * (hours)

Cost for 1303A: $ 1.6354
Cost for 1303B: $ .47957

Total cost: $ 2.11497

Amount wasted due to no one in 1303A with lights on: $.16354

Amount wasted due to no one in 1303B with lights on: $.13702

Total amount wasted: $.30056

Date: **8 Mar 92 Sunday**

Time	Amt of People in Room 1303A	Lights On/Off	Amt of People in Room 1303B	Lights On/Off
13	0	on	2	on
14	3	on	2	on
15	3	on	2	on
16	4	on	2	on
17	1	on	1	on
18	1	on	3	on
19	3	on	3	on
20	5	on	2	off
21	3	on	2	off
22	3	on	2	off
23	3	on	2	off
24	0	on	0	off
1	2	on	0	off

	1303A	1303B
Total hours of lights on:	13	7

Amount of hours with the lights on and no one in 1303A: 2

Amount of hours with the lights on and no one in 1303B: 0

Cost of Lighting = (cost/watt hour) * (bulb wattage) * (number of bulbs) * (hours)

Cost for 1303A: $ 2.12602
Cost for 1303B: $ .47957

Total cost: $ 2.60559

Amount wasted due to no one in 1303A with lights on: $.32708

Amount wasted due to no one in 1303B with lights on: $ 0

Total amount wasted: $.32708

Date: **10 Mar 92 Tuesday**

Time	Amt of People in Room 1303A	Lights On/Off	Amt of People in Room 1303B	Lights On/Off
17	7	on	5	on
18	4	on	10	on
19	Class	on	Exam	on
20	Class	on	Exam	on
21	Class	on	Exam	on
22	2	on	2	on
23	2	on	0	on
24	2	on	0	on
1	0	on	0	off
2	0	off	0	off
3	0	off	0	off
4	0	off	0	off
5	0	off	0	off
6	0	off	0	off

	1303A	1303B
Total hours of lights on:	6	5

Amount of hours with the lights on and no one in 1303A : 1

Amount of hours with the lights on and no one in 1303B : 2

Cost of Lighting = (cost/watt hour) * (bulb wattage) * (number of bulbs) * (hours)

Cost for 1303A: $ .98124
Cost for 1303B: $ .34255

Total cost: $ 1.32379

Amount wasted due to no one in 1303A with lights on: $.16354

Amount wasted due to no one in 1303B with lights on: $.13702

Total amount wasted: $ .30056

Date: **9 Mar 92 Monday**

Time	Amt of People in Room 1303A	Lights On/Off	Amt of People in Room 1303B	Lights On/Off
17	2	on	2	on
18	1	on	1	on
19	1	on	0	on
20	2	on	2	on
21	0	on	2	on
22	0	on	0	on
23	5	on	0	on
24	0	on	1	on
1	0	on	0	on
2	0	off	0	off
3	0	off	0	off
4	0	off	0	off
5	0	off	0	off
6	0	off	0	off

	1303A	1303B
Total hours of lights on:	9	9

Amount of hours with the lights on and no one in 1303A: 2

Amount of hours with the lights on and no one in 1303B: 3

Cost of Lighting = (cost/watt hour) * (bulb wattage) * (number of bulbs) * (hours)

Cost for 1303A: $ 1.47186
Cost for 1303B: $ .61659

Total cost: $ 2.08845

Amount wasted due to no one in 1303A with lights on: $.32708
Amount wasted due to no one in 1303B with lights on: $.20553

Total amount wasted: $.53261

Room usage for 1303F and 1303H

Date: **7 Mar 92 Saturday**

Time	Amt of People in Room 1303F	Lights On/Off	Amt of People in Room 1303H	Lights On/Off
10	0	off	0	off
11	0	off	0	off
12	0	off	0	off
13	0	off	1	on
14	0	off	0	on
15	0	off	1	on
16	2	on	0	off
17	0	on	0	off
18	0	on	0	off
19	0	on	2	on

Date: **8 Mar 92 Sunday**

Time	Amt of People in Room 1303F	Lights On/Off	Amt of People in Room 1303H	Lights On/Off
13	0	on	0	off
14	0	on	2	on
15	0	on	2	on
16	0	on	2	on
17	0	on	1	on
18	0	on	1	on
19	0	on	0	off
20	0	on	1	on
21	0	on	3	on
22	0	off	3	on
23	0	off	2	on
24	2	on	1	on
1	0	off	1	on

Date: **9 Mar 92 Monday**

Time	Amt of People in Room 1303F	Lights On/Off	Amt of People in Room 1303H	Lights On/Off
17	4	on	2	on
18	2	on	1	on
19	0	on	2	on
20	0	on	6	on
21	1	on	3	on
22	0	on	3	on
23	0	on	1	on
24	0	on	0	off
1	0	on	0	off
2	0	off	0	off
3	0	off	0	off
4	0	off	0	off
5	0	off	0	off
6	0	off	0	off

Date: **10 Mar 92 Tuesday**

Time	Amt of People in Room 1303F	Lights On/Off	Amt of People in Room 1303H	Lights On/Off
17	0	on	6	on
18	0	on	5	on
19	5	on	1	on
20	4	on	3	on
21	5	on	2	on
22	3	on	3	off
23	2	on	0	on
24	2	on	2	on
1	2	on	2	on
2	2	on	2	on
3	2	on	2	on
4	0	off	2	on
5	0	off	0	off
6	0	off	0	of

Lighting Analysis

Suggestions:

1) Lock all classrooms

- Lock all 163 classrooms used for lectures on campus (includes departmentally controlled rooms)

Drawback:
- insufficient studying room for students

2) Lock some classrooms

- Lock half of the classrooms, allowing the other half of the rooms for studying

3) Add new lights to rooms

- Would allow control for overhead and slide show presentations
- Not necessary since Systems Design rarely have slide shows/movies as part of normal lectures
- Overheads can be seen with all lights on

4) Reflectors

- Proper reflecting of available light can reduce number of lights needed

5) Sectional Lighting

- Different light switches for different areas of the classroom
- Allows option of turning sections of lights off during slide shows/movies
- Students wishing to study in rooms need only to turn on necessary lights for task

6) Re-distributing lights

- 1303B has insufficient lighting according to light meter readings taken
- To fix this problem, with no added material cost:
    - Side blackboard lights (from 1303A) can be taken and put in the ceiling of 1303B
    - Fourth year study room has 39 working lights and some of these lights can be used

7) Motion Detectors

- Not a logical idea for classrooms

8) Dimmer Switches

- Would require an entire reconfiguration/rewiring of classroom lights
- Dimmers only helpful during films/slide shows
- Not feasible for 1303A/1303B since students are not exposed to many films/slide shows

9) Scheduling of Classes

- Schedule smaller classes in smaller rooms to free up the larger classrooms during the day for other activities by other students who do not have class

10) Permanent Signs

- Reminds students to turn off lights when they leave the room
- Could have a framed sign to make it permanent

11) Automatic Light Switches

- Automatically turns off the lights in classrooms at 5pm
- Automatically turns off the lights every hour afterwards
- Reduces occurrence of lights on while room is empty

Proposal:

- Sectional lighting solves most of the issues (eg. reduces usage of light when only few students in room, option to turn off portion of lights during films)
- Incorporate motion detector with use of sectional lighting
- Add signs to remind students to turn off lights when leaving room
- Only rewiring would be necessary

Other Recommendations:

1) Motion detectors in offices

- There are 61 offices in Systems Design
- Professors often leave their lights on while they go to class or to meetings

2) Computer Rooms

- Each computer uses about 150W (according to Plant Operations)
- Encourage students to turn off computers after use
- Incorporate reminders in logon/logoff procedure
- Post signs

Christine Burke
Khin Kyone
Sophia Lee

For: Prof. Chandrashekar

The following constants are used in the calculations found in Table 1. This information was obtained through plant operations, the registrar's office, and the collected data .

1. The type of lights are 34 watt cool white fluorescent lightbulbs.
2. There are 74 working lights in 1303A (presently the 3B room).
3. There are 31 working lights in 1303B (presently the 2A room).
4. There are 163 lecture rooms on campus.
5. The cost of electricity is 6.5 cents/kwh.
6. The cost of a fluorescent lightbulb is $ 1.67.
7. The average number of off-class hours that lights are on in a room is seven (7).
8. The average number of hours that a room is used on the weekend with the lights on is 25 hr/weekend.
9. Fluorescent lightbulbs are changed once every two (2) years.
10. A university school year is 323 days or 46 weeks. This is assumed because during the last two weeks of every term (three terms in a year) there are no classes and no examinations.
11. The cost of labour is $ 25/hr.
12. A weekend includes Saturday and Sunday.

Table 1: Summary of Calculations

Suggestion	Cost ($) (for a class)	Cost ($) (for campus)	Savings ($) (for a class)	Savings ($) (for campus)	Payback (yrs) (for a class)	Payback (yrs) (for campus)
Lock all rooms	0	0	317	51671	immediate	immediate
Lock half the rooms	0	0	158.5	25836	immediate	immediate
Reflectors	2100 + 1050	342300 + 171150	1391	226733	2.2	2.2
Sectional Lighting	50 + 400	8150 + 65200	341	55583	1.3	1.3
Motion Detectors	150 + 400	24450 + 65200	154	25102	3.6	3.6
Scheduling classes	0	0	n/a	n/a	n/a	n/a
Permanent Signs	20 + 25	3260 + 4075	154	25102	3.5 months	3.5 months
Automatic Switches	undetermined	undetermined	154	25102	undetermined	undetermined
Proposal	220 + 625	35860 + 101875	494	80522	1.7	1.7

* Please note that costs have been broken down into material and labour costs respectively.

Workshop Proposal Mark

1. Definition

Although, it did take us some time before we were able to narrow our topic to the final idea, this delay is due to many factors:

- Our group was only formed when we came back to campus
- We wanted to do something that would benefit the environment and the University, instead of a project that was only theoretical. These criteria required serious thought and several conversations with those already involved in energy reduction on campus. Also, we had to determine what information we would be able to obtain. At first, we assumed that we would be able to see records of how much energy the University uses and it's breakdown for the different buildings.

8 / 10

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2. Distinguish

It is quite evident that our topic is unique and different from other projects that have been done. We can see this be the lack of documentation that exists for our topic, even in Plant Operations. Considering the amount that is wasted on lighting in classrooms, we believe that our project is relevant and could possibly produce some changes.

10 / 10

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3. Data

We took an innovated way to verify and backup the need for changes in the present lighting system for classes. We monitored two classrooms for 5 weekdays (outside of class) and 3 weekends, counting how many students are using the room,and if none are, then whether or not the lights are on. With this data we managed to obtain realistic costs and possible benefits of different solutions. Although, more data is required for accurate results, we had limited time and resources (people to record the data).

10 / 10

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4. Alternatives

The main part of our project was to derive and investigate the feasibility of different solutions to reduce the energy consumption due to lights in classrooms. The main drawback for this was the difficulty in obtaining the costs associated with each idea.

10 / 10

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5. Feasibility

We did a cost analysis on each alternative solutions, along with the payback period. This shows the feasibility of each solution. Also, our proposal was quite feasible with a payback period of 1.7 years and continual savings of over $80,000 annually for the campus.

9.5 / 10

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6. Experiment

Not applicable.

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7. Analyze

Apart from creating alternate solutions to improve the classroom lighting energy consumption, these alternatives were analyzed in terms of their cost, time requirements, cost benefits and classroom environment improvement. We were thorough and did a complete and accurate analysis.

9 / 10

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8. Decisions

For our proposal we combined some of the cheapest and easiest solutions, that still filled our criteria, provided savings and is an acceptable arrangement for the students. Throughout the project we have had to make several assumptions because certain data is not available. We have always tried to choose the most logical assumptions when we could not obtain definite answers.

9 / 10

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9. Communications

We have felt that our communications skills have improved during this project due to the amount of time we have spent talking to professionals about our topic and trying to get information. We were continuously meeting with and calling Horst Beyerle. From the refernces, it can be seen that we spoke to many people.
Apart from our outside communication, our within group communication has been excellent. Our personalities get along great and this has aided us in being efficient and not getting on each others nerves.

9 / 10

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10. Technical

Although our project was practical and the university could profit from our proposal, we believe that our workshop was not that technical. We should have researched the actual lights (e.g. compact fluroescents).

7.5 / 10

Professor Chandrashekar,

This was a very quick response to your question of what we thought we deserved. The only reason that it looks so professional is because the NeXT machines were the only ones available, and we have forgotten how to write normally (e.g. pen and paper). Also, with the NeXT, it is easy to make documents look nice. Thank you for supporting the funding for the NeXT computers for Systems Design.

Although, at times we have written a few "light" remarks, we do believe in what we wrote. We have worked continously hard (as can be seen from our lab book), and we believe that we have worked to the best of our abilities given our resources.

For these reasons, our proposed mark (for what it's worth) is 91%. But we will not be disappointed with a higher mark.

Thank you for all your help and support,

Christine

Khin

Sophia