"How eager we are to learn about the Journey from Edison's warm yellow glow incandescent electric lights to solid LED lighting, but a 22 page syllabus with detailed course requirements. Come on!!!"

YES all you need to know about 466 is detailed herein

Spring 2018 from Jan 16 to 3 May

Schedule and Grading of ECE 466

Integrated Lighting Systems: 3 Credits

SEE: http://www.engr.colostate.edu/ECE466

Please forgive this lengthy syllabus, schedule and grading missive, but with lectures and a lab there are lots of issues to cover. To keep it all clear and fresh, I will send out a weekly memo usually a week in advance detailing:

Last week's efforts

This week's efforts and what's due the coming week (e.g. Pop Quiz)

Next week's efforts and due dates for all new assignments

Grading Summary:

1. HW Assignments: 10 %
2. Talk / Paper # 1: 20 %
3. Talk / Paper #2: 40%
4. Pop Quizzes: 20%
5. Spice models of C-C-L and L-L-C resonant drives for fluorescent lights: 10 %

THIS TOTALS 100%

In addition, one can earn more points as follows:

Class participation not attendance: 3 % for active contributions in or out of class. Do not be a potted plant in class.

OPTIONAL group Extra credit up to 7% on the topic of LED based Li-Fi as compared to Wi-Fi and 5 G networks. This is a semester long OPTIONAL Ex credit that can be done as a group and sent before 26 April to g Collins by email attachment. Do not send to CANVAS or to the grader

Topics to cover in the 466 extra credit include:

a. **Bandwidth and channel numbers are to be compared between mm wave 5 G and LED based Li-Fi for an apples to apples comparison**

b. **Bandwidth and channel numbers are to be compared between Wi-Fi and LED based Li-Fi and cost comparisons as well as for devices and new infrastructure**

c. **Security issues between Wi-Fi and LED based Li-Fi**

d. **Secure noise and interference free networks in planes for LED based Li-Fi comm.**

e. **Other topics your group chooses such as LED based Li-Fi receivers, emitters and transceivers.**

Look at an image of the earth at night to grasp the lighting energy use, to fight back the night in our 24/7 world and allow us more opportunities: **http://antwrp.gsfc.nasa.gov/apod/image/0011/earthlights_dmsp_big.jpg**

The goal of this memo is to let students know EVERYTHING about 466 in one document in a clear, plain and intelligible manner. But it took too many pages because it includes ALL that is expected in 466. Do not despair of its length as every week I will provide an abbreviated list of what's due that week and upcoming weeks.

Li-FI is introduced in the course when we cover LED lighting. See these two Ted Talks to familiarize yourself:

1. http://www.sciencealert.com/li-fi-tested-in-the-real-world-for-the-first-time-is-100-times-faster-than-wi-fi

2. http://www.ted.com/talks/harald_haas_a_breakthrough_new_kind_of_wireless_internet?utm_campaign=social&utm_medium=referral&utm_source=facebook.com&utm_content=talk&utm_term=technology

For those interested in Extra credit view the videos and then use 4 PPT slides for each talk to summarize what you learned—total of 8 PPT slides for up to 3 points on your final grade.

Aims/Goals of ECE466 Course are found on pages 2-5

Evaluation and Grading Criterion is found on pages 6-7

Thumbnail first 16 weekly lecture topic sketches are found on pages along with TWO TALKS GUIDANCE pages 7-9

Information and Guidance for the two Group Talks is found on pages 10-14of this memo

Schedule of Due Dates 466 for Spring 2018 is found in table form on pages 15-16 of this memo

OUTLINE of Detailed Weekly Topics Covered in Class is again in table form **found on pages 15 to 22 of this already too long memo.**

Note students in both 466 and 465 may use very similar talk # 2 in both classes but with slightly different emphasis—see both syllabi.

- **Disclaimer Notice:**
  - Up to date in class announcements always supersede this preliminary guide.
  - If you have further questions ask me in class or the grader so everybody benefits.

    - **Class Time:** Tuesday and Thursday, 8- 9:15 AM in ENGRG, Room B3
    - **Instructor:** Prof. George Collins, Email: **gcollins@engr.colostate.edu**

    Send to me all GROUP 466 PPT talks and talk WORD Papers but not to the grader or to CANVAS

Upload ALL Spice labs, HW and Pop Quizzes in 466 to Canvas

Grader: Fateh Elsherif
Email: fateh@rams.colostate.edu

Aims/Goals of ECE466 Course:

This course will instruct undergraduates from all areas of study, about the creation and evolution of efficient full color lighting sources. Lighting accounts for >20% of total USA electric energy use. This includes: home and office lighting, street lighting and even back lights to LCD screens. This evolution of ever more efficient electric power to light power conversion brings associated energy savings and helps climate change concerns with CO_2 generation of fossil fuels. We claim this is saving in light power equals efforts in **GREEN** solar/ wind energy generation. Indeed I show that the move from incandescent to LED lighting saves in the USA alone 230 Million MW-Hr or 10^{11} KW-Hr of electric generation. It does more for climate change than green solar or green wind generation. In short, in the discussion of energy sources as well as energy savings, who is right and who is wrong is too simple. Each side is right in some sense but how do you parse that. Again pop quizzes in 466 all attempt to give you practice doing just that.
You will learn in this course to use hard numbers, "metrics" with "units", such as energy cost in $/Lm or $ per Joule for driving light sources. This way, quantitative comparisons of Lm / W may be made between incandescent, fluorescent and LED light sources, where Lm is light intensity and W is electric power. There is no free lunch as different light sources cost different amounts of money to purchase and different energy costs to operate as well as differing maintenance costs. All this adds up to total costs as the final comparison. Again the effort is to inform you, the future energy policy makers, of the visionary possibilities, the practical realities and the return on investment time which also depends on local utility rates.
Another focus in the course is the apparent little energy savings say in backlighting LCD screens with LEDS. This little saving is multiplied by say 4 billion such devices in computer screens, TV screen, gaming screens and cell –phone screens. In the case of lighting luminaires the number of energy saving devices can be 10 -100 billion. Therefore lighting is where energy savings are emerging and where 20 % of energy is used. Motors consume 70% of electricity and variable frequency motor drives reduce this consumption by >20 %. The common thread in all energy savings is low cost high efficiency power electronics
A major aspect of the course is INCREASED energy efficiency in units of "Negawatts", "kill-a-watts", or energy saved in the new LED lighting. Just increasing lighting by 20 % would save energy costs, reduce greenhouse gas and CO_2 emissions, and reduce the need to build new hydrocarbon fueled power plants, solar plants or even wind as the energy savings are that big.
I will conclude in class notes that LED lighting adoption has been held back primarily by initial costs of LED luminaires and this is rapidly falling. The trend is new LED manufacturing methods that combine light emitters and drive electronics on the same IC GaN chip containing LEDS and drive electronics. Costs are dropping. But you and your group make your own determination in your TALKS; especially talk # 2 which can integrate in luminaires electronics, optics LEDS and heat removal.

Recommended Reference books:

1. Lighting Control technology and applications by Robert Simpson (found free online and adopted as class text). This is supplemental only and **not required**.
2. Power Electronics Handbook third edition by Muhammad Rashid (found online)
3. Fundamentals of Heat and Mass Transfer by Theodore Bergman (found in the library and used by ME department for heat and mass transfer)

Instructor Philosophy

ECE Students are the most important people at CSU.

Not dependent on faculty.

Faculty is dependent on them.

Not an interruption of our work.

They are the purpose of being at CSU.

Students are doing us a favor when they come to our office.

We are not doing them a favor by serving them.

Students are part of our business, not outsiders.

Not just a CSU ID number.

They are flesh and blood human beings with feelings and emotions.

Students come to us with their needs and wants.

It is our job to address them with courteous and attentive treatment.

Students are the life blood of this and every university.

Without them we would close our doors.

DON'T EVER FORGET THIS!

All work in 466 is in groups with opportunities for individual grades as well. Here are few guidelines regarding GROUP HW and POP QUIZ submissions. Decide your group members and leader of the group among yourselves. Elected group leaders will send the list of confirmed group members both to me and to the grader. Also please try to maintain equal number of members in each group before sending the list of confirmed group members. **Please contact myself or the grader if the grading is not accomplished in a timely manner.**

Groups will give students a chance to discern and make judgements about truth versus facts in the book and lectures. In groups engage in pop quiz ideas and decide for yourselves.

- Upload all 466 GROUP HW/POP QUIZ answer sets, SPICE LABS to Canvas.
- **Grader:** Fateh Elsherif fateh@rams.colostate.edu

For HW and Pop Quizzes

1) Preferably write your solutions in MS PowerPoint. Number of slides may vary depending upon the solution.

2) Please use the file name format as- "ECE 466_HW/POP QUIZ#_Group#".

3) Only group leader will submit the final ppt of HW/POPQUIZ to CANVAS.

4) Please cc all the group members when submitting the final ppt for HW/POPQUIZ.

Text Book: Lighting Control technology and applications by Robert Simpson (found FREE online) https://www.uploady.com/#!/download/zXwJ_nodNWT/e_VcDC7EdeLe7pdu. Let me know if you cannot download. The rest is from instructor notes found on the ECE website http://www.engr.colostate.edu/ECE466

To access the ECE 466 web notes you must use:

- **Username:** student
- **Password:** Lights
- Note that student is not capitalized while Lights is capitalized.

SEE A COOL WEBSITE ON LED LIGHTING:
Ephesus Lighting who lit the 2015 super bowl and again in 2017

For your use throughout the class see:
Some lighting company websites are given below for you use in HW and Pop Quizzes as they have tutorials and application notes that answer many HW and Pop Quiz questions:

Lutron, GE Lighting, Advance (Philips), Sylvania

The Institute of Lighting Engineers UK has a series or reports useful to this course. Minolta Japan has a 60 page booklet “Color control from perception to instrumentation. IESNA publishes a series of “Recommended Practices booklets” on lighting. Surprising to some, incandescent warm yellow glow bulbs are now ILLEGAL, See for example **www.energy.ca.gov/commision/commissioners/rosenfeld_docs/index.html** **and www.efficientpowersupplies.org/efficiency_news.asp.**

I digress: Street lights with microphones can triangulate PRECISE location and time of gunfire or explosions to allow for faster police/fire response to correct locations in an emergency.

GUIDE to getting maximum value and success from ECE 466:

1. **GROUP EFFORTS** in ECE466 are the key to your success and also teach many soft skills needed in your future job where group efforts are the rule.
2. Best way to accumulate points is to provide **LOTS of daily questions** in class or to provide me with **outside materials relevant to the class**. Another way is to ask MEANINGFUL questions during in class presentations by other groups. Folks who interrupt class or bring to lectures quality questions or important comments will earn these points. Listen and take minimal notes in class – but interrupt the lecture flow often with cogent questions. Be shameless, never be like a potted plant during lectures. Use lectures to get a wider angle view of LIGHTING ISSUES.
3. Enjoy the wonder of LIGHTING ISSUES from traffic and train signals, outdoor lighting, indoor lighting, computer screen illumination and decorative architectural lights.
4. **Class website: my 466 lecture notes will be posted each week and found at** http://www.engr.colostate.edu/ECE466

Evaluation and Grading:

1. 5 Homework’s = **10%**
2. 5 Pop Quizzes = **20%**
3. 2 Spice Labs = **10% AC high frequency L-L-C and C-C-L resonant circuits for fluorescent light fixtures**
4. Group Talk #1 = **20% (15 points PPT slides and 5 points for WORD paper).**
5. Group Talk #2 = **40% (35 for PPT talk and 5 for WORD paper)**

1-5 above totals 100 points.

THIS TOTALS 100%

But in addition, for those interested in extra credit read below:

AGAIN,in addition one can earn more points as follows

Class participation not attendance: 3 % for active contributions. Do not be a potted plant in class.

OPTIONAL group Extra credit up to 7% on the topic of LED based Li-Fi as compared to Wi-Fi and 5 G networks. This is a semester long OPTIONAL Ex credit that can be done as a group.

Topics to cover include:

a. **Bandwidth and channel numbers are to be compared between mm wave 5 G and LED based Li-Fi for an apples to apples comparison**
b. **Bandwidth and channel numbers are to be compared between Wi-Fi and LED based Li-Fi and cost comparisons as well as for devices and new infrastructure**
c. **Security issues between Wi-Fi and LED based Li-Fi**
d. **Secure noise and interference free networks in planes for LED based Li-Fi comm.**

e. **Other topics your group chooses such as LED based Li-Fi receivers, emitters and transceivers.**

Class participation is to provide LOTS of daily questions in class or to provide me with outside materials relevant to the class. Another way is to **ask MEANINGFUL questions during in class presentations** by other groups. Folks who interrupt class or bring to lectures **quality questions or important comments** will earn these points. **If you disagree with my conclusions in lectures, you do your own research and decide for yourself. You will be rewarded with extra credit points if you disagree with me and use a cogent rational explanation why you disagree after you clearly state my position you disagree with.**

466 Grading Scale:
Letter grades for ECE 466 are on an A to F scale with plus minus fine tuning on all letter grades.

A-F GRADING SUMMARY with plus minus fine tuning for 466
Letter grades for ECE 461 are on an F to A scale with plus minus fine tuning on all letter grades.

Score (X)	**Letter Grade**
X > 100	A+
X > 96	A
X > 93	A-
X > 91	B+
X > 86	B
X > 83	B-
X > 81	C+
X > 76	C
X < 59	F

No C minus grades allowed

*If you are experiencing difficult situations that are affecting, or could potentially affect, your academic success, please contact **Student Case Management** as soon as possible (http://www.studentcasemanagement.colostate.edu/ E203 Newsom Hall, 970-491-8051). Difficult situations can include issues such as medical, mental health, personal or family crisis, illness, or injury. If students request extensions or considerations due to difficult situations, I typically require documentation from Student Case Management. In addition, I urge students to contact me in advance of deadlines about such issues.*

For making referrals, their contact information is:
Student Case Management
E203 Newsom Hall
970-491-8051
vpsa_student_case_management@colostate.edu
http://www.studentcasemanagement.colostate.edu/

CSU Academic Integrity Policy:

- This course will adhere to Academic Integrity Policy of CSU General Catalog and Student Conduct code. It is expected in this course that all students will not give, receive or use any unauthorized or undocumented assistance in their group efforts as well as individual efforts. All appropriate sources need to be referenced and it's best to do in IEEE format for references/sources. Unauthorized audits violate the Student Conduct code.
- **Accommodation for Students with disabilities:** I will follow CSU policy given at http:rds.colostate.edu or call CSU telephone extension 6385

Thumbnail weekly lectures sketch:

Week # 1: 16/18 Jan

- Brief history of lighting: As we lit the night from campfires, to street lights, to modern inside living rooms the lighting technology changed. Why some lights are now illegal.
- **NL 5 Spice lab on series L-L-C circuits, for better understanding fluorescent lighting power, is due on 4 Feb.**

Week # 2: 23/25 Jan

- Incandescent lighting and its Legacy: Part One: Edison screw to connect light fixtures to the grid and TRIAC wall dimmers that are an installed base do dim the lights from bright yellow to soft red.
- **NL 5 Spice lab on C-C-L resonant circuits is due on 11 Feb.**

WEEK # 3: 30 Jan/1 Feb

Incandescent lighting and its Legacy: Part Two: We continue the basic understanding of TRIAC controlled dimmers along with the LEGAL grid requirements on ALLOWED power factor and ALLOWED harmonic content.

Week # 4: 6/8 Feb

Gases enclosed in a partial vacuum are excited to emit radiation by the passage of electric current. High Intensity Gas Discharge Lights and Traditional Fluorescent lights start this topic. AC to DC conversion will be required for the first step of providing electric power for both fluorescent and LED lighting, so we review rectification and the LEGAL grid requirements on ALLOWED power factor and ALLOWED harmonic content. Fluorescent lighting power electronics goes from AC grid to DC to 30-50 KHz AC to provide the best drive. Beyond fluorescents are high intensity discharge lamps for car headlights, stadium lighting and highway and parking lot high pressure sodium das discharge lights.
FOR THE REST GO TO THE END OF THE SYLLQBUS

L-C-C SPICE resonance reviews the two simulations in the region between the two resonances that occur for R_{LOAD} = infinity and zero extremes as well as a few points in-between. It is in this region the dimming of fluorescent lights occurs after breakdown and the switch to the other resonant curve. Varying f_{DRIVE} allows one to dim the fluorescent light.

- **Spice lab on L-C-C resonance and L_L-C circuits form a starting point for TALK # 1.**
- Beyond driving fluorescent lights LCC is employed for driving high intensity discharge lamps for car headlights, stadium lighting /highway and parking lot high pressure sodium discharge lights.

Weeks 5 and 6 for STUDENTS TALK #1: Tues. Feb 13 – Thur. 22 Feb,

Group Talk # 1 In 2018 we have 30 students so form FOUR GROUPS of 7-8 students each. Each group presents for one class period. Goal of Talk # 1 is to improve communication skills. It will spot problems early in both presentations and papers and fix them, so you do not repeat mistakes in talk # 2. Presentations from ALL groups will occur BEFORE middle of March-exact dates TBA. Again you get a group grade with individual grades for extra credit, where merited. Written portion must be in Word format and oral presentation slides in PowerPoint Format. Talk # 1 and paper # 1 has a common theme for all groups, so your group can hear other groups cover the same materials and learn by positive or negative example of how to present materials. For example SPICE simulations of L-L-C or C-C-L circuits in the region between the two resonance curves where controlled dimming can occur for fluorescents. .

Possible topics for talk #1 CAN with permission leap ahead to LED lighting and surprising use of lighting fixtures both indoors and outside on streets for the Internet of things (IoT).
I prefer you cover lighting systems. For example, progress in IoT networked wireless lighting systems such as Li-Fi or incorporating in an interior room luminaire with a RF transmitter at 10 W to deliver 1 W anywhere in a room to make a network of lighting sensors and light sources. This system then enables involves sensor SCADA data feeding system control software such as GE's Predix to optimize lighting efficiency in a commercial building.

Also include the DARK SIDE

How Cybercriminals Target the Physical Data Center

Digital light monitoring platforms offer many benefits, but can also open the door to cyber security threats. If your group wishes address the risks, covering:
- Cyber security concerns for data center remote monitoring platforms
- Key steps to keep data private and infrastructure systems secure from hackers
- Practices of a secure development lifecycle
- Recommended design attributes and best practices for the a cloud-based monitoring platform

Both talks/papers are done as group efforts to simulate your future environment in the workplace. Group/team efforts are required to get students familiar with the team efforts that they will encounter in the workplace and so they better understand the dynamics of team work

TALK #1 is worth 20 points total

- **Individual PPT Presentation is grading out of 15 for Talk #1 is as follows:**
- **1. TECHNICAL ACCURACY 9/15**
- **2. PPT Slide ORGANIZATION 3/15**
- **3. CLARITY OF MATERIAL-SHORT LIST OF TOPICS IN DEPTH COVERAGE BETTER THAN MANY TOPICS VERY SHALLOW DOVERAGE 1/15**
- **4. PROPER SPELLING GRAMMAR REFERENCES 1/15**
- **5. FOLLOWING THE MEMOS ON TOPICS TO BE COVERED 1/15**

- **GROUP WORD PAPER GRADE OUT OF 5 for Talk #1 is based AS FOLLOWS:**
- **1. TECHNICAL ACCURACY 2/5**
- **2. PAPER ORGANIZATION 1/5**
- **3. CLARITY OF MATERIAL-SHORT LIST OF TOPICS IN DEPTH COVERAGE BETTER THAN MANY TOPICS VERY SHALLOW DOVERAGE 1/5**
- **4. PROPER SPELLING GRAMMAR REFERENCES .5/5**
- **5. FOLLOWING THE MEMOS ON TOPICS TO BE COVERED .5/5**

WEEK # 7: 27 Feb / 1 March

- LED Solid State Lighting Devices: Part One: Physics of PN light emission.

- **Spice labs on buck and boost PWM converters using NL 5 are assigned and are due after spring break on 22 March. Spice lab on the L-C-C resonance circuit is due Thur. 1 March.**

Week # 8: 6 March Tues only we have class

- LED Solid State Lighting: Part Two: Both Intensity and Color control by PWM electronic drives of current to strings of LEDS. Both

NO CLASS Thur. 8 March before spring break.

Week # 9: SPRING BREAK: 10-18 March

Week # 10: 20/22 March

- We return to Collins lectures for Electronic Powering LED luminaires for homes and offices.

This enables students to understand PWM dimming of LED loads over >20: 1 range without the “SHOWSTOPPER” light intensity flicker issues that induce medical problems such as migraines or seizures.
.
Grid powered LED electronic drives have two stages: one, PFC (power factor correction with boost or buck PWM converters) and a DC to DC conversion to drive the LEDS with constant current variable by duty cycle control. USB powered electronic drives for LEDS only has DC to DC conversion circuits of buck, boost or buck - boost types. Modern buildings have DC as well as AC receptacles to plug into. We will cover AC to DC conversion for both single and three phase using both diodes and SCRS.

Week # 11: 27/29 March

- Heat removal with LED fixtures or luminaires include, at too high LED junction temperatures which causes drop in light intensity, color shifts, shortened LED operating life and other harmful effects. Heat Removal Solutions in LED lighting are employed to maintain lower LED junction temperatures.

Week #12: 3/5 April

- I give lectures on Electronic Dimmers for LED lighting that allow a dynamic range of 20: 1 dimming levels, yet avoid light intensity FLICKER that causes in people seizures at worst and headaches at best to folks exposed to flickering LED lighting.

Week #13 and 14 Group Talk # 2 worth 40 points, Tues.10 April- Thur. 19 April, is on ANY IN DEPTH TOPIC focused on IT lighting systems.

Normally conventional LED lighting uses AC to DC conversion followed by DC-DC conversion to drive LED’s with a variable current to achieve light dimming without light intensity flicker. But at the low end FLICKER ARISES as a showstopper health problem. LED lighting of LCD Screens from early fluorescent back lights to present LED white side lights for brighter screens with greater contrast. The evolution 3-D LCD screen technology started with special polarized glasses to create 3D stereoscopic effects. It has now evolved to glasses free 3-D viewing of screens from 3M and Microsoft that allows left and right but also front and back action that appears to jump out of the screen for movies and games.

Key technically to dimming LEDS using legacy dimming fixtures is the measurement and decoding of the dimmer phase angle changes over 180 degrees and dimming angles must be converted into an on duty cycle in the PWM LED current drive that varies from 0 to 1.0 to achieve 20”1 dimming without light intensity flicker. Also include in talk # 2 DIRECT AC driven LED lighting such as thee Acrich2 AC LED module from Seoul Semiconductor

Week 15 **Thur. 24 April- Thur. 26 April.**

Week # 16: 1/3 May

- Organic LEDS (OLEDS), which create their own light and do not require back lighting, are presented. OLED screens are formed on ultra-thin (100 micron) roll able glass or plastic sheets that allow roll up screens and new OLED manufacturing methods promise to decrease costs of OLEDS and increase lifetime of OLEDS, especially blue OLEDS.

Go to the end of this syllabus to see a MORE detailed list of due dates and weekly lecture topics

ECE 466 classes end on Thur. 3 May

Guide to the Due dates of 466 assignments will be sent out weekly:

I will send out a **weekly memo** reminding you of last week's material, this week's materials and next week's material. I do not want any possibility of poorly explained assignments, nor lack of what is expected in assignments. I hope it clearly states the following three points:

1. What prior assignment is due that week (e.g. Pop Quiz, Chapter HW, upcoming talks, etc). In general the weekly Pop Quiz is due the following week it was assigned and on **Thurs**. The HW is assigned as we cover materials and not weekly, it is due the following week it is assigned on **Tues.**
2. I highlight newly assigned material for that coming week and future due dates for all new assignments within a month's interval. This is to better help students guide their time, as I know you have other courses. Due dates for ALL pop quizzes and HW are given below in the syllabus.
3. Finally this course is lots of work in the beginning of the semester but much less work in the final 4 weeks of the semester, to give you more time for TALK #2 and for other courses.

Send **corrected PPT slides and WORD papers one week after your in class talks and all extra credit assignments** by email attachment ONLY to: gcollins@engr.colostate.edu
DO NOT send to CANVAS or the grader

Guide through the 466 grading minefield: Four Major Parts A-D given below :
I repeat for clarity. The 466 basic grading is in **four parts** with opportunity for both group and individual efforts counting roughly equally as follows. **GROUP EFFORTS** are required for all **four parts**, but with **individual efforts** taken into account.

A. Information and Guidance for the Homework's:
5 HW Q/A assignments (10 % final grade)
I believe the quality of students questions are more important than the answers they give to questions from the instructor because they are in the learning phase. Your Group creates each week, either PURE ANSWERS or a mix both questions and answers (Q and A) about the week's 466 lectures. Yes, you get to form ALL the HW questions some weeks, as well as your answers for the questions you pose. For variety sometimes I pose ALL questions and some weeks both types of HW issues are included. Each week will be unique and you will be notified in advance. As the course moves on, the students provide more challenging questions and answers based on outside readings assigned weekly.

B. Information and Guidance for the Pop Quizzes: 5 Pop Quizzes (20 % of final grade)

5 pop quizzes (**4 points each**) based on material given in 466 class lectures, as well as Google Scholar searches. At minimum the pop quizzes are tailored to both keep you current with lecture topics. This also a chance to "drill deep" into a topic I assign with your group team dividing the work. Use my class notes, the text and articles from the web.
Pop Quizzes are to be done as a group effort not as an individual effort. Split up the work among your group members and put all answers in PPT format with cogent and to the point bullets not windy paragraphs with large font sizes in say Ariel black. All pop quizzes are to be done in PowerPoint.

C. **Information and Guidance for the TWO Required SPICE Labs (L-L-C and L-C-C circuits) for Driving Fluorescent Lighting: 10 % of the final grade. Buck and boost labs are optional and for for extra credit only.**

2 Spice labs easiest done in **NL 5 or LT Spice**(L-L-C and L-C-C circuits are equally weighted. NL5 or LT Spice is for those interested in dimming fluorescents. In dimming when we vary f_{DRIVE} ffor breakdown of gas discharges followed by a switch to another resonance curve as shown in high frequencies for dimming gas discharges we move through the twin resonances of L-C-C networks.

Why I suggest for 466 the LT or the NL5 Spice Simulator vs. the steep learning curve Cadence Virtuoso

NL5 Spice Simulator and Cadence Virtuoso are programs that allow users to design circuits in a schematic view and then run various simulations on the designs. While they both have schematic capture and simulation capabilities, the extent of those capabilities are very different. Cadence Virtuoso is an industry standard software package that provides full IC design, from schematic design and simulation all the way up to physical chip layout. Cadence requires detailed parts libraries in order to simulate real components sold by different vendors, which is needed when designing real life chips. The main advantage Cadence has over NL5 is its extensive capabilities. Cadence offers every type of simulation, design check, and various tools a designer would ever need in a circuit-design package, and is regularly used in large-scale chip design in the IC industry. Some of the advanced simulations Cadence offers include simulating different design corners, Monte Carlos sweeps, and process variations. When used at its full potential, Cadence is a very powerful circuit-design program.

Cadence has two main disadvantages however, which are cost and complexity. It is a very expensive software package that typically costs companies and school thousands of dollars per license. For the most part, only large organizations can afford Cadence, so smaller companies or individuals must look elsewhere. In addition to its high cost, Cadence is also a very complicated program to master. It usually takes years just to learn to use a lot of the more common schematic simulation modes. Using layout and the more advanced simulation modes further increases the complexity of the program. In short, in order to use Cadence to its full potential and “get your money’s worth”, one must spend several years mastering the software. For students trying to use a circuits program for the purpose of learning circuit theory, Cadence is an ineffective option since it is so expensive and takes so long to learn how to use.

NL5 on the other hand is a very good candidate to use for educational purposes. To start, it is completely free to download and use. Unlike Cadence, it can be installed on Windows or Mac, and is a very small program (Cadence is typically run on Linux, and is a massive software package, memory-wise). In addition, NL5 is extremely simple to use compared to Cadence. It has a very straightforward GUI that is not overloaded with unnecessary content. The components in the somewhat limited library are all very basic and easy to assign values to. Simulations (AC, transient, and parametric sweeps) are pretty easy to master after going through a step-by-step tutorial of them. Another important point is that nearly all of NL5’s functionality is always visible and available to the user on the schematic design screen. This means that it is not necessary to search through bloated drop-down menus for different parts of the program. Because of its simplicity, NL5 is relatively easy for students to pick up and use to build basic circuits and run basic simulations for the purpose of learning how different circuits work.

While the simulation capabilities of NL5 are much lower than Cadence, it is the better choice for educational settings because of its low cost (free!) and simplicity. Using a program like NL5 allows students to spend most of their time running simulations and analyzing circuits, and not troubleshooting the program itself or trying to learn how to use basic functionality.

D. Information and Guidance for the two Group Talks: 60 % of 466 grade in total

You get a group grade for the paper but individual grades for the PPT presentations. Written portion must be in **Word format** and oral presentation slides in **PowerPoint Format**. Both talks/papers are done as group efforts to simulate your future environment in the workplace. Group/team efforts are required to get students familiar with the team efforts that they will encounter in the workplace and so they better understand the dynamics of team work. For group efforts Microsoft has versions of Word and Power Point that reside on servers at Microsoft Office Live —moreover this allows MULTIPLE users to log on and work on the SAME document together. I strongly recommend Microsoft SkyDrive for student cooperative projects/talks/papers that many students in a group can share edits as they occur. It is deeply integrated with Microsoft Office on both Windows and Mac's and is free. A remarkable way to "see" data and try to use gapfinder.com in your talks is http://www.youtube.com/watch?v=hVimVzgtD6w

Practice makes perfect in PPT presentations. After you take a job PPT presentations will be a big part of your job. "Kaizen" is a Japanese word for continual improvement and is common in manufacturing as pioneered by Toyota. Presentation skills too can be honed through repetition, listening to talks and critiques of our own talks. Hence for both talks all student groups talk on the same topic.

I encourage 466 students to form groups. By dividing the work and handing in a single group effort you learn group skills.

Note students in both 466 and 465 may use very similar talk # 2 in both classes but with slightly different emphasis—see both syllabi.

In both talks for 466 the government's role in fostering new lighting technologies that save energy should be discussed. To be economically competitive in the future each country has to **MINIMIZE energy costs**, as innumerable studies show that low cost energy drives Gross Domestic Product (GDP). Moreover slow global warming is a reality and most proposed energy saving or energy generation solutions to the problem are sought. Compromises need to be made on a realistic basis and this is open for your group to discuss, where 4-6 students each present a portion of the talk. **Your talks should be crystal clear and the reasoning and conclusions sensible.**

Group Talk #1:

20 % of final grade (15 points PPT slides and 5 points for WORD paper).

Send both revised PPT slides and WORD paper to me not the grader:

Instructor: Prof. George Collins, Email: gcollins@engr.colostate.edu

Advice for Talk # 1 was given above: For example an overview of progress in IoT networked wireless lighting systems and progress in networked luminaires to connect all components to a network of lighting. Street lights could be turned on and off with traffic load. ASIDE: Street lights with microphones or smoke detectors can triangulate PRECISE location and time of gunfire or fires to allow for faster police or firemen response to correct locations in an emergency.

Alternatively a legacy wal ldimmer talk could involve: "RESONANT AC CIRCUITS For Dimming of CFL Fluorescents: L-L-C versus C-L-L Circuit Approaches". Your AC dimmer operates in between dual resonance curves. Focusing on this in between region versus frequency comparison should be crystal clear for achieving dimming of fluorescents.

In this case to be compatible with a legacy SCR dimmer we need a decoder to relate phase angle set by wall dimmer TRIAC to be related to the varying operating frequency of the high frequency RF applied to the two electrodes in a fluorescent light via a voltage controlled oscillator. Similar requirements for LED lights translate phase angle to duty cycle are required. Given your Spice simulations this should be very easy for fluorescents . The two simulations in the region between the two resonances that occur for R_{LOAD} = infinity and zero extremes as well as a few points in-between. It is in this region the dimming of fluorescent lights occurs after breakdown and the switch to the other resonant curve. Varying f_{DRIVE} with a VCO allows one to dim the fluorescent.

***Your alternative talk # 1 should also cover high intensity gas discharge lamps for cars and stadium lighting. As well as cover* inductively-coupled fluorescent electrode less lighting as distinguished from capacitive driven fluorescents with inner electrodes and external electronic ballast.**

In particular visit the website of "New American Technology" and investigate their Induction fixtures or the website of Sylvania and Everlast Induction Light. Induction driven fluorescents is a response to LED technology and makes fluorescents a stronger competitor to LED's in HIGH CEILING applications as regards:

1. **80.000 hour lifetime without maintenance.**
2. **Freedom from color shifts yet provide high color rendition light.**
3. **Large area light source as compared to LED small area light source**

Goal of Talk # 1 is to improve communication skills. It will spot problems early in both presentations and papers and fix them, so you do not repeat mistakes in talk # 2. Presentations from ALL groups will occur BEFORE middle of March. Exact dates TBA. Talk # 1 and paper # 1 has a common theme for all groups, so your group can hear other groups cover the same materials and learn by positive or negative example of how to present materials.

GRADING TALK # 1 worth 20 points total

Individual PPT Presentation is grading out of 15 is as follows:

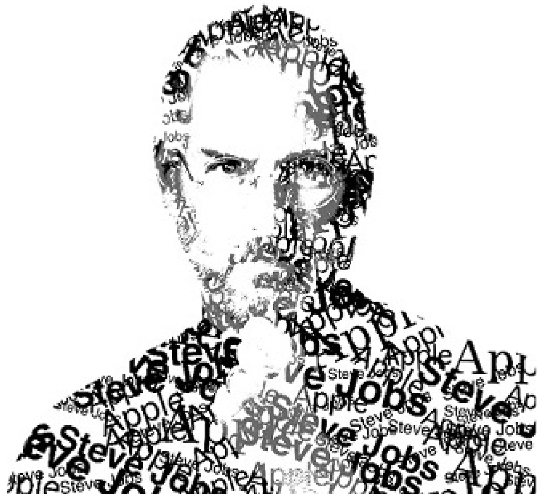
1. TECHNICAL ACCURACY 9/15
2. PPT Slide ORGANIZATION 3/15
3. CLARITY OF MATERIAL-SHORT LIST OF TOPICS IN DEPTH COVERAGE BETTER THAN MANY TOPICS VERY SHALLOW DOVERAGE 1/15
4. PROPER SPELLING GRAMMAR REFERENCES 1/15
5. FOLLOWING THE MEMOS ON TOPICS TO BE COVERED 1/15

GROUP WORD PAPER GRADE OUT OF 5 is based AS FOLLOWS:
1. TECHNICAL ACCURACY 2/5
2. PAPER ORGANIZATION 1/5
3. CLARITY OF MATERIAL-SHORT LIST OF TOPICS IN DEPTH COVERAGE BETTER THAN MANY TOPICS VERY SHALLOW DOVERAGE 1/5
4. PROPER SPELLING GRAMMAR REFERENCES .5/5
5. FOLLOWING THE MEMOS ON TOPICS TO BE COVERED .5/5

Send both revised PPT slides and WORD paper by email direct to me. Do not send to the grader or to CANVAS:

Instructor: Prof. George Collins, Email: gcollins@engr.colostate.edu

Presentations Steve Jobs Style



When you give a presentation, you face at least two hurdles.

First, you need to sell yourself as a credible spokesperson on your topic. Audiences need to believe in you-and that's hard enough.

Second, you need to sell your ideas so that people come away inspired, persuaded and enlightened.

Steve Jobs did both-with incredible skill. Widely considered one of the most gifted presenters ever, Jobs understood how to deliver memorable speeches in a seemingly effortless, engaging manner. His conversational tone, simple yet compelling word choice and masterful use of slides and other props helped reinforce his message in winning ways.
You'll learn how to develop key presentation skills, including how to:

- **Integrate Aristotle's "Big Three"-logos/ethos/pathos-to win over audiences.** Learn how to blend logic, credibility and emotion to enliven your remarks.

- **Convey big ideas or central themes via multiple channels.** From audience giveaways to props to slides, apply the Steve Jobs approach and align all available tools to drive home key points so that people cannot help but remember them-and buy into them.

- **Think in threes.** To explain complex processes (from chemical reactions to financial formulas), learn to cluster your main points in threes. Your audiences will thank you.

- **Use bluntness and directness.** Rather than drop hints or dance around controversial positions follow Steve Jobs' example and state your case boldly and succinctly.

- **Embrace simple language.** If you need to explain complex ideas, you must speak in complex terms. Right? Well, Steve Jobs was a master at communicating complicated concepts in unmistakably clear words. Develop tools to translate your speech into plain English that's compelling and hard for anyone-of any background or educational level-to ignore.

- **Start staff meetings with an edge.** Steve Jobs did not begin staff meetings with touchy-feely happy talk. Instead, he often provoked people or expressed disappointment in some aspect of the team's performance. But by the end of the meeting, everyone left in a positive frame of mind- inspired and validated. Find out how Jobs pulled that off.

GRADING Group Talk # 2: 40 % final grade (35 for PPT talk and 5 for WORD paper)

Send both revised PPT slides and WORD paper by email direct to me. Do not send to the grader or to CANVAS:

Instructor: Prof. George Collins, Email: gcollins@engr.colostate.edu

This talk is on the topic of combining IoT (e.g. SCADA reporting light sensors) and IT (e.g. GE Predix or Siemand Mindsphere on a cloud or in house server) to make a robust self-organizing lighting system for a building that optimizes lighting throughout the day and minimizes power required. .

Talk # 2 woth 40 total points. Individual PPT Presentations for talk # 2 are graded out of 35 is as follows:

1. **TECHNICAL ACCURACY 25 / 35**
2. **PPT Slide ORGANIZATION 5/25**
3. **CLARITY OF MATERIAL-SHORT LIST OF TOPICS IN DEPTH COVERAGE BETTER THAN MANY TOPICS VERY SHALLOW DOVERAGE 1/25**
4. **PROPER SPELLING GRAMMAR REFERENCES 1/25**
5. **FOLLOWING THE MEMOS ON TOPICS TO BE COVERED 3/25**

GROUP WORD PAPER for talk # 2 is graded out OF 5 based AS FOLLOWS:

1. **TECHNICAL ACCURACY 2/5**
2. **PAPER ORGANIZATION 1/5**
3. **CLARITY OF MATERIAL-SHORT LIST OF TOPICS IN DEPTH COVERAGE BETTER THAN MANY TOPICS VERY SHALLOW DOVERAGE 1/5**
4. **PROPER SPELLING GRAMMAR REFERENCES .5/5**
5. **FOLLOWING THE MEMOS ON TOPICS TO BE COVERED .5/5**

The same talk # 2 can be given in BOTH ECE 466 and ECE 465 if students are enrolled in both courses.

Schedule of Due Dates 466 Spring 2018:

Date	Week #	Assigned Homework, Pop Quizzes and Labs	Tuesday Due	Thursday Due
16/18 Jan	1	HW #1, Series Resonance Lab and Pop Quiz #1, are optional		

23/25 Jan	2	HW #2, Parallel Resonance Lab and Pop Quiz #2, are optional	HW#1 is due. (**23 Jan**)	Pop Quiz # 1 due (**25 Jan**)
30 Jan / 1 Feb	3	HW #3, L-C-C Resonance Lab and Pop Quiz #3, are required. .	HW #2 is due. (**30 Jan**)	Pop Quiz # 2 and Both Spice labs on series and parallel resonance are due on **1 Feb.**
6/8 Feb	4	HW #4, and Pop Quiz #4, are assigned. L-L-C resonant circuit Spice simulation is required.	HW #3 is due. (**6 Feb**)	Pop Quiz # 3 due is due (**8 Feb**)
13/15 Feb	5		GROUP TALK #1 13-22 Feb	GROUP TALK #1 HW 4 is due. **(15 Feb)**
20/22 Feb	6		GROUP TALK #1	GROUP TALK #1, Pop Quiz # 4 and LLC Resonant Lab due. **(22 Feb)**
27 Feb / 1 March	7	HW #5 and Pop Quiz #5 are assigned.	GROUP TALK #1 revised PPT slides and Word papers from Talk # 1 due (**27 Feb**)	Revised PPT slides and Word papers from Talk # 1 (**1 March**)
6/8 March	8	HW #6 and Pop Quiz #6 are optional	HW #5 due and Revised PPT slides and Word papers from Talk # 1 (**6 March**)	Pop Quiz #5 due and Revised PPT slides and Word papers from Talk # 1 (**8 March**) **No class on Thur. 8 March.**
13/15 March	9		**Spring Break –**	**Spring Break**

20/22 March	10	HW #7 and Pop Quiz #7 are optional	HW #6 is due. (**20 March**)	Pop Quiz #6 due
27/29 March	11	HW #8 and Pop Quiz #8 are optional	HW #7 is due. (**27 March**)	Pop Quiz #7 due. (**29 March**)
3/5 April	12		HW #8 is due. (**3 April**)	Pop Quiz #8 due. (**5 April**)
10/12 April	13	**HW # 6-10 and Pop Quiz # 6-10 are optional extra credit ones.**		GROUP TALK #2 (**10 - 19 April**) Revised student PPT and Word papers from Group are due one week after presentations
17/19 April	14		GROUP TALK #2	
24/26 April	15	**Group Extra credit due before 26 April**	GROUP TALK #2 and revised student PPT and Word papers from Group Talk #2, one week after presentations	
1/3 May	16		Revised Student PPT and Word papers from Group Talk #2 due one week after presentations	Revised Student PPT and Word papers from Group Talk #2 one week after presentations Last day of ECE 466 classes. (3 **May**)

OUTLINE of Detailed Weekly Topics Covered in Class:

Materials Covered in Lecture # 1

1. Physics of Light.
2. Ancient and pre-modern artificial light Devices.
3. Early Incandescent Light:
    a. Prior creation of vacuum technology conditions
    b. Hot wire in vacuum and blackbody radiation
4. Edison Engineering:
    a. Edison Mechanical Screw to connect bulb to the grid.
    b. Long life W filament and later addition of halogen gas to

Eliminate by chemical vaporization bulb blackening from evaporated W deposited on inner bulb wall.

c. Best Lumens per Watt of 20.
d. Low initial cost (0.5 $) of incandescent light bulb.

5. Incandescent bulb from lighting warm yellow glow hero to outlaw that pleas for survival and why the change.
6. Correlated Color Temperature (CCT) of light sources in units of ^{o}K versus color rendering index (CRI) in units of 0 to 100. Two different methods of quantifying light sources.

Materials Covered in 466 Lecture # 2

1. Legacy Wall Fixture DIMMERS for Resistive Load Incandescent lights:
   a. Thyristors or SCR's as AC power controller via phase angle control of conduction current.
   b. TRIAC as controller for both positive and negative half cycles of AC currents.
   c. Attraction of Legacy wall fixture dimmers to incandescent light consumers.
   d. The installed base of billions of wall dimmers located between the grid AC and light fixtures.
   e. Phase angle control over a range from 0 to 180 degrees of current conduction angle via gate control on TRIACS.
   f. Power Factor issues with dimmers: S,P,Q triangle:
      1. Displacement power factor.
      2. Distortion power factor.
      3. Total power factor.
   g. Grid Harmonics created by dimmers and international laws controlling grid harmonics caused by dimmers up to 50 f_{G}.

Materials Covered in Lecture # 3

1. Low cost vacuum technology legacy allows for low pressure gas containers one meter long that one runs current through to create wide area light from excited gas atoms.
2. Various gas mixtures used for wide area light emission for varying light output color mix.
3. Various phosphors used on inner walls of gas discharge lamps for light output color mix control in meter long gas discharge tubes.
4. Classic meter long fluorescent light fixture with Ar-Hg low pressure fill gases and color tunable phosphors for tunable light output versus wavelength with high intensity and high pressure gas discharge lamps and applications.
5. Advent of compact fluorescent bulb with Edison screw to replace incandescent light bulb with 60 Lm/ W versus 20 Lm/ W from incandescent lights.
6. Economic and energy cost comparison of fluorescents versus incandescent lights.
7. High Frequency Electronic Drives for Fluorescents: L-C-C and L-L-C impedance matching circuits for starting and dimming fluorescents.
8. Review of Resonant circuit Spice assignments.

Materials Covered in Lecture # 4

1. 30- 50 kHz versus 60 Hz V-I characteristics of fluorescents.
2. Generation of tunable 30 – 50 kHz power drive electronics for fluorescents from AC grid power via two step rectification and followed by inverters to create high frequency AC from DC.
3. Single and three phase non-linear rectifiers for DC creation from grid AC. Role of total power factor and harmonics in rectifier circuits.
4. Role of dual resonant L-C-C and C-L-L buffer circuits placed between the variable frequency drive electronics and the fluorescent light fixture.
5. Variable frequency drives for ignition and dimming.

Materials Covered in Lecture # 5

1. Integrated lighting systems with light and occupancy sensors activating various lighting options from bulbs to skylights to SAVE energy.
2. Electronic controllers for integrated lighting systems:
    a. Digital Addressable Lighting interface (DALI) Standard.
    b. Zigbee Standard.
3. Modern Inverter Technology for creating high frequency AC from DC:
    a. Variable frequency Fluorescent light drives.
    b. Variable frequency Motor Drives.
    c. Inverters for solar and wind energies to create grid frequency AC and for FACTS devices in the power grid.
    d. Synthesis of AC wave forms by PWM methods and the need for higher frequency switches.
    e. Employing 30- 50 kHz insulated gate bipolar transistors (IGBTS) versus 1 kHz thyristors.
    f. Details on PWM DC to AC conversion for both single phase and three phase AC.
    g. Modern Motor Drives and MW level Solar inverters at grid frequencies.

Materials Covered in Lecture # 6

1. Z (f) plots of resonant circuits to better classify Resonant Converters:
    a. Series R-L-C resonance with R load and $Q_S = Z_C / R$.
    b. Parallel Resonance with R-C load and $Q_P = R / Z_C$.
    c. L-C-C and C-L-L resonance and the role of dual resonances for open circuit versus short circuit resistive loads.
    d. Variable frequency drive AC to achieve both HV breakdown and LV dimming in fluorescent lights.
2. Advanced Energy (AE) DC Power supplies employing L_S –C_S –C_P circuits and advantages of same.

Materials Covered in Lecture # 7

1. Review of properties of L_S –C_S –C_P and C_S- L_S- L_P circuits and Spice Assignments.
2. Z_{IN} (f) for L_S –C_S –C_P and C_S- L_S- L_P circuits.
3. Variable frequency Controls as we go from ignition to operation to dimming with both L_S –C_S –C_P and C_S- L_S- L_P circuits.
4. Parallel resonance Spice Simulation.
5. L_S –C_S –C_P resonance Spice simulation.
6. Look ahead to LED lighting: Are we being LED to a brighter future???
    a. Role of legacy constraints from wall dimmers, available phosphors and Edison screws with LED lighting.
    b. Tale of three bulbs as regards energy efficiency, bulb operating life, light output in Lm /W and total costs including initial cost and operating costs.
        1. Incandescent driven by grid directly or via a dimmer
        2. Fluorescent requires a grid AC to DC to high frequency AC conversion driver chain.
        3. LED requires a grid AC to DC Converter with PFC as well as a PWM current driver chain that decodes the change in phase angle from a dimmer to a on time for a PWM converter.

Materials Covered in Lecture # 8

1. Solid state LED Color Spectrum as a light source: no need for vacuum conditions of prior art.
2. Lm / W comparison:

a. Incandescent @ 10-20.
b. Fluorescent @ 50.
c. LED @ >150.
d. USA saves 230 million MW-hr of electricity needs or 100 230 MW power plants or 136 million less tons of coal burn or 5 trillion ft^3 of CO_2 generation.

3. What's inside both colored and white light LEDS.
4. Beam like LED Intensity pattern versus omnidirectional intensity patterns from CFLS and incandescent bulbs.
5. Detailed comparison of LONG operating life of LEDS versus short lived incandescent bulbs and fluorescent lights and associated economic and energy costs.
6. Promise of solid state manufacturing costs to drive LED lighting costs down by a factor ten from 2015 prices via integration of LEDS and electronics on one IC chip.

Materials Covered in Lecture # 9

1. LED light intensity and color spectrum versus current and operation temperature:
    a. Loss of efficiency for LEDS operating at high current and temperatures unless heat removal is implemented.
    b. Change in output color spectrum operating at high current and temperature unless heat removal is implemented.
    c. Details of Achieving White light LED light sources with proper mix of LEDS and phosphors:
        1. Red shifted light.
        2. Blue shifted light.
        3. Pure White light.
    d. Quantifying Color of LED light sources by established color science in black and white:
        1. Commission on Illumination Standards (CIE) 1931.
        2. Correlated Color Temperature (CCT) in units of ^oK.
        3. Color Rendering Index (CRI) in units of 0 to 100.
        4. Chromaticity Charts from Commission on Illumination Standards (CIE) extended for screen displays and projection TVS.
    e. Commercial LED vendors and typical specs as well as environmental impact of LEDS. Sorra the new all GaN future low cost LED contender combining LEDS and electronics on 1 GaN chip.

Materials Covered in Lecture #10

1. Review of the power factor for lighting fixtures arising from the non-linear nature of SCR dimmers and rectifiers as well as the linearization attempts of PWM power electronics to make PF approach unity and harmonics approach zero.
2. The conflicting requirements of the grid to make power factor close to unity and harmonic content up to 50^{th} harmonic within regulatory standards.
3. Light Software for illumination Modeling:
    a. WebBench LED Architect from National Semiconductor.
    b. IPS software from Infinion.
4. Six point AC to DC rectifier for commercial building DC power for LED lighting:
    a. Platt River Power Authority.

Materials Covered in Lecture #11

1. Subtle V-I changes for different color LEDS.
2. High power high brightness LED lighting issues: PFC, insulation and isolation.
3. LED Drivers that provide:

A. PFC Boost Circuits after the non –linear rectifier to create DC from the grid AC with unity power factor and no harmonics.
B. Dimmer phase control decoders to measure varying angle of SCR dimmer and then to create electronically appropriate D_{ON} of PWM circuits driving the LEDS to obtain flicker free dimming over all dimmer phase angles, especially at low AC power.
    a. Analog control of phase decoder and $D_{ON.}$
    b. Digital control of phase decoder and $D_{ON.}$
C. Drivers for series and parallel LED Strings in high power lighting.
D. Drivers for series /parallel combinations with constant current.

Materials Covered in Lecture #12

1. LED Drivers AC to DC current conversion at variable current levels over a factor of >20.
2. Review of various color LED V-I Characteristics.
3. Review of single phase SCR rectifier for variable DC output but with large voltage ripple at 2 f_G that must be eliminated by fast DC to DC converters to provide 1% steady DC delivered to LEDS.
4. LED flicker free dimmer electronics over 20 to 1 range accomplished by multi stage electronics:
    a. Varying Phase angle measurement from dimmer.
    b. Conversion into D_{ON} of DC converter driving the LEDS to follow the SCR dimmer.
5. LED control of the color mix by PWM control of R-G-B LED light output.

Materials Covered in Lecture #13

LED Lighting Effect on Grid of AC to DC rectifiers:

a. Total PFC issues.
b. Generation of grid harmonics.
c. Grid requirements Drives the need for correction of both issues via synthesis of grid currents using either boost or buck topology.

1. Boost converter synthesis of grid current to be sinusoidal when placed after the rectifier and R-C load. Additional role of providing fixed DC output with <5% ripple regardless of AC source variations and DC current levels.
2. CCM versus DCM mode of operation of the boost converter for sinusoidal grid current synthesis.
3. Buck versus boost PFC circuits.
4. Direct AC driven LEDS from Seoul Semiconductor with opposite polarity LED strings to both rectify and drive LEDS:
    a. Low voltage 12-20 VAC for garden lighting.
    b. High voltage20 to 60 VAC for building lights.
    c. Disadvantages early of versions: no dimming, high EMI, low efficiency, flicker and low Lm /W.
    d. New LED driver versions.

Materials Covered in Lecture #14

1. Heat generation in Units of W/ cm^2 which for LEDS is roughly .75 x I_F x V_F for W and the LED area is typically mm^2. This causes LED junction temperature to rise above ambient temperatures.
2. LED High junction temperature operation (in ^{0}K or ^{o}C) of LEDS causes problems with:
    a. Lower Lm / W.
    b. Shifts in LED color spectrum.
    c. Decreased LED lifetime.
    d. Manufacturer provided derating forward current versus Led junction T and mean time between failure LED lifetime versus LED junction T curves. Both curves are employed for LED lighting to guide design of heat removal and set maximum junction temperature.

e. Additional Temperature effects:
   I. Luminous flux decreases with T.
   II. PN junction voltage decrease with T.
   III. Efficacy (Lm / W) decrease with T.

3. Heat removal in units of Watts or J / Sec by conduction, convection and radiation to reduce LED junction temperature in steady state:
   a. Using heat conduction properties to spread high T from localized small area near the LED to a wider area open to ambient conditions.
   b. Natural or forced air flow employed to remove heat from large area to the ambient.
   c. Radiation of IR photons from the black body radiator of large area to remove heat from the large area to the ambient.
4. Equations for steady state heat conduction with thermal conductivity of various materials in units of[W / m ^oK]. Heat radiation equations in terms of T^4 in units of ^oK.
5. Natural versus forced heat loss by convection to the local ambient fluid or gas simplification to thermal resistivity concept, R_{TH} , in units of [^oC/ W]. Complete chain of heat flow Q (W) in steady state in terms of thermal resistivity so that temperature rise or fall is given at each step in the chain by: ΔT (^oC) = Q (W) R_{TH} .
6. Specialized heat removal methods.

Materials Covered in Lecture #15

1. What is holding LED lighting back beside too high cost of fixtures and too high LED junction temperatures and associated problems/limitations such as:
   a. Lower efficacy in units of Lm / W.
   b. Shifts in LED color spectrum.
   c. Decreased LED lifetime.
   d. Mean time between failure in LED lighting systems due to weakest component in the electronics drivers is usually electrolytic capacitors.
2. Low cost passive heat removal designs in LED luminaires via new thermal materials and improved passive heat sinks.
3. High Cost Active cooling technology including:
   a. Forced air by use of fans and air jet technology.
   b. Heat pipes employing heat of vaporization.
   c. Peltier active electronic cooling.
   d. Liquid fluids versus air.
4. Transient T-t effects in pulsed PWM high intensity LEDS.
5. LED environmental issues.

Materials Covered in Lecture #16

1. Glow for it: LED bulbs follow the geometric legacy of incandescent and CFL BULB geometries and Edison screws to connect to AC grid.
2. X-ray and cut out diagrams of LED BULB Luminaire showing:
   a. LEDS and any external optics to shape intensity patterns.
   b. Power electronic Drivers.
   c. Bulb phosphor coatings to tailor and shift color output light spectrum for each lighting application.
   d. Heat removal design in bulb and linear LED luminaires.
3. Linear Array of LEDS to replace linear fluorescent tubes.
4. Total Cost Economics of LED lighting from initial fixture cost, to electric bill operating cost to maintenance costs of long life versus short life luminaires.

5. Total cost savings illustrations of industrial lighting, commercial lighting and home residential lighting.

Materials Covered in Lecture #17

1. Evolution of computers and associated display screens from monochrome to full color.
2. Cell phone evolution and associated display screens from monochrome to full color.
3. LCD display back lighting evolution from back of screen fluorescents to screen periphery white light LEDS for illumination to achieve bright and full color displays over 150 cm on a diagonal.
4. Evolution of 3-D LCD screens that capture left to right and front to back screen images. 3-D started with polarized light with special viewing glasses to get stereoscopic effect. Recently screen makers evolve to 3-D without requiring special viewing glasses by 3M, Microsoft and others.

Materials Covered in Lecture #18

1. Organic light emitting diodes (OLEDS): Another contender for active matrix OLED color displays from HD to 4K with better contrast than LCD screens. OLEDS are polymers that emit their own light and do NOT NEED BACKLIGHTING, so screens are ultrathin and flexible and can be curved in geometry.
2. OLEDS for next generation lighting and wall illumination but only if costs can come down dramatically by a factor of 100 and mean time between failures increases by x 10.
3. Evolution of OLED manufacturing methods to achieve lower cost and increased lifetime OLEDS, especially blue emission OLEDS. Roll to roll web coating may allow both improvements.
4. Emission Physics and Chemistry of PN junctions in organic polymers
5. OLED passive and active matrix displays for computers, games and phones.
6. Other applications of OLEDS:
    a. Active pattern programmable wall paper and paper thin lighting.
    b. Illumination of flexible displays in clothing and fashion.
    c. OLED skin patch for photo-therapy.

Materials Covered in Lecture #19

1. Review of linear and non-linear loads.
2. Ethernet DC Input or building DC that drives PWM based intensity dimmers and PWM color mixing.
3. Interface with Legacy wall dimmer that has phase control on the AC waveform over 180 degrees on each half cycle:
    a. Analog and digital decoders from phase angle to D_{ON} in PWM LED driver electronics.
    b. Avoiding flicker issues at low light intensity.
    c. Two stage LED dimmer electronics is costly:
        I. PFC circuits.
        II. PWM circuits that employ decoders from phase angle of dimmer to D_{ON} of PWM.

And on and on with **new lectures till the end of 466**. For example SEE the following: https://www.youtube.com/watch?v=5uCL79X24kA