Pratt

MSCI220C – Fall 2020

The Science of Light

Charles Rubenstein, Ph. D.
Professor of Engineering & Information Science

Materials Courtesy of Dr. Mark Rosin

Session 11 - *VIA REMOTE LEARNING*

Monday 11/09/20 2:00pm - 4:50pm

Tuesday 11/10/20 5:00pm - 7:50pm

Revision 1

Zoom Meeting Info

You should plan on logging into the Zoom meeting at least five (5) minutes before the start of class.

MSCI220C-05: MONDAYS 2:00pm *(1:45pm Start)*
https://pratt.zoom.us/j/98423013879?pwd=OElKZjZiRXhWQ29YQ0hLbVFLTVo0Zz09
Meeting ID: 984 2301 3879
Passcode: MonLight

MSCI220C-02: TUESDAYS 5:00pm *(4:45pm Start)*
https://pratt.zoom.us/j/98876758765?pwd=dHBhbDZjQ01kN3RsUFFML2pJbmRVdz09
Meeting ID: 988 7675 8765
Passcode: TuesLight

Please see the file 220_Zoom_info.pdf for further information.

Zoom Meeting Recordings will be posted by Thursdays

Challenges? email me at **crubenst@pratt.edu** !

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Zoom Office Hours Info

Dr. Charles Rubenstein <crubenst@pratt.edu>
Professor of Engineering & Information Science
Faculty Office: ARC G-49 (Brooklyn Campus)

Fall 2020 Office hours

You MUST email me, not later than 12:00Noon on Tuesday, with preferred meeting time(s) to arrange for a fifteen (15) minute, Zoom session during my 10:00am – 2:00pm Office Hours.

Wednesday Office Hours Zoom Meeting
https://pratt.zoom.us/j/5691762059?pwd=SnpseEE2NnVQbVNvUE8veEZxTENvUT09
Zoom Meeting ID: 569 176 2059
Passcode: Office

Challenges? ***Send me an email: crubenst@pratt.edu***
or, c.rubenstein@ieee.org

Subject Line: 220 Office Hours

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MSCI220C – Class Topics

1. ***Introduction to Waves and Light***
2. ***Ray Tracing***
3. ***Reflection & Curved Mirrors***
4. ***Snell's Law and Lenses***
5. ***Photography and the Eye (2 classes)***
6. ***Color in Nature (2 classes)***
7. ***Color Vision***
8. ***Polarization***
9. ***Light Sources (2 classes)***
10. ***Optical Devices***

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FINAL Schedule: MSCI220C– Fall 2020 – *ONLINE*

Mon, Tues	Notes
8/24, 8/25	1. Introduction: Introduction to Waves and Light
8/31, 9/1	2. Ray Tracing
9/14, 9/8	3. Reflection & Curved Mirrors; *Research Paper Topic Due*
9/14, 9/15	4. Snell's Law and Lenses
9/21, 9/22	5. Photography and the Eye - 1; *Project Proposal/Presentation Due*
10/5, 9/29	6. Photography and the Eye - 2
10/5, 10/6	7. Color in Nature - 1; *Midterm Exam emailed & DUE 10/11*
10/12, 10/13	8. Color in Nature - 2; *Project Proposal Update Due*
10/19, 10/20	9. Color Vision; *Midterm Review; Research Paper Draft Due*
10/26,10/27	10. Polarization; *Final Project Proposal Due; Research Paper Returned*
11/2, 11/3	NO CLASS SESSION THIS WEEK
11/9, 11/10	11. Light Sources - 1; *Research Paper Due; Final Project Paper Due*
11/16, 11/17	12. Light Sources - 2
11/23, 11/24	13. Optical Devices *Final Exam emailed by 9am/12NoonET-11/29*
11/30, 12/1	14. *Final Project Materials and Final Exam Due by1pm/4pmET-11/29*
12/7, 12/8	*Final Project Presentations – in class*

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www.CharlesRubenstein.com/220

11Week Folder = *Week 11 materials*

20fa11.pdf = *This slide set**

20fa11_h.pdf = *slide set as handouts**

* *My goal is to post this set of slides online by the Friday evening one week before class…*

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In Today's Class #11:

Session 11 ***(11/09 Mon; 11/10 Tues)***

- ***DUE:*** **Research Paper; Final Project Paper**
- ***Review of Homework Assignment #11***
- ***Lecture: Light Sources - 1***
- ***In-class problem solving***

Session 12 ***(11/16 Mon; 11/17 Tues)***

- ***Review of Homework Assignment #12***
- ***Lecture: Light Sources - 2***
- ***In-class problem solving & Review of Example Final Project***

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Science of Light - Final Project

Final Project: (30%)

'Midterm'/Draft Proposal = 10% (5% proposal, 5% oral presentation)

Project = 20% (5% proposal update, 15% PowerPoint presentation)

Final Project Topic:

Students will identify a specific topic in the syllabus that will become the basis for their final project. The project proposal is expected to include possible forms that the project can take in terms of function and physicality.

A one-page (*doc or pdf*) overview of the proposed project will be reviewed by the instructor. Final must be presented as both a paper and PowerPoint

(See ProjectAssignment.pdf)

- ✓ ***'Midterm'/Draft Topic Proposal Due: 21/22 September***
- ✓ ***Oral Presentation: In Class 21/22 September***
- ✓ ***Topic Proposal Update: 12/13 October***
- ✓ ***Final Proposal Due: by 12:00Noon ET 26/27 October***
- ✓ ***Final Project Paper Due: 9/10 November***

NEW: Final Project PowerPoint SUBMISSION: 30 Nov / 1 Dec

Final Project PowerPoint Presentation: In Class 7/8 December

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Final Project UPDATES

PLEASE REVIEW THE FILE: ProjectAssignment.pdf

Final Project:

*For your final project, you will create an original piece of work in a medium of your choice on any subject related to the **science of light**. The piece must convey a scientifically accurate understanding of the course material, or other material related to the science of light similar to those we have reviewed in previous and future project reviews.*

Final Project Proposal Due: 26/27 October

*A short proposal of 250 words **and a minimum of two images** on what you intend to do for this assignment must be submitted. You must say what area of the science of light you intend to cover, and the means (e.g., creating a sculpture) by which you intend to do so.*
*- Proposals are to be submitted as a single **DOCX file.***
- You will receive feedback via edits to your project proposal page.

Final Project Paper Due: 9/10 November

Final Project PowerPoint Submission: 30 Nov or 1 Dec

*Only materials emailed to **crubenst@pratt.edu** will be accepted.*

Final Project PowerPoint Presentation: In Class 7/8 December

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PROJECT Topics: Monday Section

MSCI220C-02	Preliminary Topic
Dyuti	Optical Illusions
Nick	Camera Obscura
Jeff	Optical Illusions
Fenny	Experimental Art
Deanna	B&W Optical Illusions
Jenna	Schlieren Optics & Sound Visualizations
Zoe	Optical Illusions Beyond 2D
Ginger	Color Theory
Chloe	Eye Glasses & Contact Lenses
Meryl	Ray Tracing & Reflections in Art
Parry	Sustainable Lighting
Mya	Optical Illusions

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PROJECT Topics: Tuesday Section

MSCI220C-05	*Preliminary Topic*
Audrey	Optical Illusions & Nearsightedness
Mitch	Colors and Mood
Maddison	Colorblindness
Eliza	Colors and Emotion
Juan	Optical Illusions in 3D Environments
Kwang	3D / Polarization

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About Emailing me your Assignments

Assignments are due not later than Noon on class days.

1. *You must submit proposals and papers as a word processed document in either rtf, doc, or docx format - let me know if you have another format you will be using. It needs to have a proper heading so if printed out we know who created it!*
2. *As necessary, take photo(s) of your work and insert the photo(s) into the word-processed document*
3. *Your project(s) should be submitted as a write-up AND an at least six (6) slide PowerPoint presentation.*

Save your paper proposal, etc., files as
***lastname_paper_xx.docx** (etc.),*

Save your project, etc., files as
***lastname_project_xx.pptx** (etc.),*
*where **xx** is your section (02 or 05).*

***Then email your file** to me:*
crubenst@pratt.edu
*With the subject line **SciLight XX Paper** (etc.)*

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Questions?

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The Science of Light
Session 11

Lab Exercises
Discussion

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Color of Light Exercise – Page 1

Equipment Required:

You will require your CMY paints, Red Filter and three colors of lasers as well as a Water bottle and (if easily available powdered) milk

Mixing the Color Wheel:

- **Green:** use equal parts cyan and yellow (*slightly more cyan than yellow*)
- **Blue:** use a lot more cyan than magenta
- **Red:** use a little more magenta than yellow

Begin with lightest color first when starting to paint your wheel. Paint two layers if time permits.

TO DO: *Snap a picture! Spin the wheel – Do you get more colors?*

Part 1: Subtractive Color Mixing:

a. First, we're going to try subtractive color mixing.
b. Mix CMY (starting with the lightest color) to produce a color wheel including RGB (see instructions above and class example).
TO DO: *Snap a picture!*

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Color of Light Exercise – Page 2

Part 2. Additive Color Mixing

a. Use the laser pointers to combine light from the lasers.
b. Try all the two-color combinations: RG, RB, and GB.
c. Now try all three: RGB, to get CMY and white.
TO DO: *Snap a picture of each combination!*

Part 3. Light and Paint

a. Look back in your class notes to the four examples we did on color mixing. First, write what you think will happen if you shine **red light on green paint.**
b. Now, fold the red filter so it is twice as thick and cover your smart-phone light to produce red light.
c. Now, shine the **red light** from the smartphone + filter on your color wheel.

TO DO: *What color is the **green paint,** and does it match your prediction?*

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Color of Light Exercise – Page 3

Part 4. Light Scattering

a. First, mix a little milk (powder) into your bottle of water. Then, from the top, shine your red laser into the mixture. Now swap your red laser for your blue laser and try again.
b. If both beams travel all the way through, add more milk (powder) and try shining the lasers again.
c. Repeat until only one of the lasers shines all the way through.

TO DO: *Which color travels further in milky water?*
Which is scattered away through the sides of the bottle?
We'll discuss your answers in the next class.

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Prisms Exercise – Page 1

I) Prisms and Spectrums Lab – LIGHT BOX & LASERS

There are a number of light sources you can use for this lab. The sun (*go outsi*de), the light from a small lamp passing through a slit to create a beam (*also known as a light box*), or your phone (*See section II*).

For each exercise, after you have completed it with a regular light source, repeat with two of your different colored lasers – Red, Green, Blue.

I.1) Set up the light source so that the one slit of the platform is in front of the source and a beam of light passes out of the slit. Let that beam of light strike the prism as shown here:

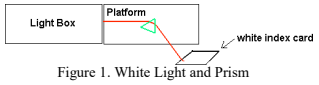

Figure 1. White Light and Prism

Be sure the beam passes through the surfaces of the prism, NOT the corners!

Hold a piece of white paper or white index card at least a half a meter away observe the light striking the card.

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Prisms Exercise – Page 2

I) Prisms and Spectrums Lab – LIGHT BOX & LASERS, *continued*

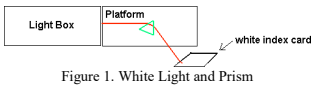

Figure 1. White Light and Prism

I.2) Sketch and label what you see.

Did red light or blue light get bent more? Is this what you expect? Why or why not?

Does the spectrum spread out as you move the card away from the prism?

I.3) Now repeat the activity using a blue and a red laser.

Which laser bends more? Why?

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Prisms Exercise – Page 3

I) Prisms and Spectrums Lab – LIGHT BOX & LASERS, *continued*

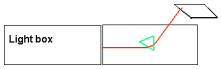

Figure 2. White Light and Reversed Prism

I.4) Going back to white light now, reverse the prism as shown in Figure 2.

Did the colors reverse so that the color that was bent the smallest angle, is still bent the smallest angle? Why is this the case?

I.5) *OPTIONAL – ONLY DO IF YOU HAVE A SECOND PRISM!*

Leaving the first prism set up to show a spectrum, insert the second prism as shown. Get the adjacent surfaces of the two prisms parallel, but NOT touching. Is there a spectrum in the final output beam? Why or why not?

Figure 3. White Light and DUAL Prisms

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Prisms Exercise – Page 4

II) Prisms and Spectrums Lab – Using a Mobile Phone

For this set of exercises, you will use your mobile phone and a light-box slit:

Figure 5. Cell Phone Light and Prism

For each exercise, after you have completed it with a regular light source, remove your phone and the slit and repeat with two different colored lasers.

II.1) Set up the light sources so that the one slit of the platform is in front of the source and a beam of light passes out. Let that beam of light strike the prism.

Be sure the beam passes through the surfaces of the prism, **NOT the corners**!

Hold a piece of white paper at least a half a meter away observe the light striking the card.

Sketch and label what you see.

Did red light or blue light get bent more? Is this what you expect? Why or why not?

Does the spectrum spread out as you move the card away from the prism?

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Prisms Exercise – Page 5

I) Prisms and Spectrums Lab – Using a Mobile Phone, *continued*

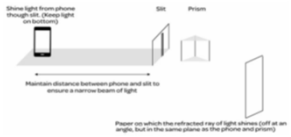

Figure 5. Cell Phone Light and Prism

II.2) Now repeat the activity using a blue and then a red laser. You may need to use (cigarette) smoke to visualize the laser beams. ***DO NOT LOOK INTO THE BEAMS DIRECTLY!*** look into the prisms from above to see how the laser light travels.

Which color of laser light bends more? Any guesses why?

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Prisms Exercise – Page 6

I) Prisms and Spectrums Lab – Using a Mobile Phone, *continued*

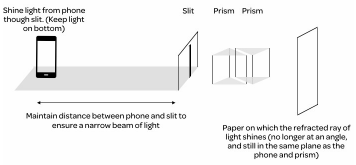

Figure 6. Cell Phone Light and Dual Prisms

II.3) ***OPTIONAL ONLY DO IF YOU HAVE A SECOND PRISM!***

Leaving the first prism set up to show a spectrum, insert the second prism as shown. Get the adjacent surfaces of the two prisms parallel, but NOT touching.

Is there a spectrum in the final output beam? Why or why not?

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Total Internal Reflection Lab – Page 1

I) Total Internal Reflection Lab – Light Box

I.1) Set up a prism as described in figure 1 and use one of your **laser** pointers as the light source instead of the Light Box.

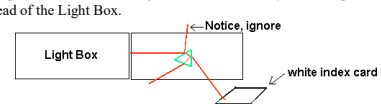

Figure 1. Laser Light and Prism

Be sure the beam passes through the surfaces of the prism, **NOT the corners!**

Notice, and then ignore, the ray reflected off the first surface.

I.2) Draw a sketch to show where the first exit ray goes after leaving the prism.

I.3) Now draw the second exit ray that is totally internally reflected.

(If you look from above the prism, you should be able to see this ray reflecting off the inside of the prism.)

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Total Internal Reflection Lab – Page 3

II) Total Internal Reflection Lab – Mobile Phone, *continued*

Figure 2. Laser Light and Prism

II.3) Now, be sure you can achieve the configuration above and draw it again below.

II.4) As you adjust the prism, sometimes the light will not be Totally Internally Reflected from the inside of the prism. That is, some light is escaping from the far side of the prism. Draw the diagram when some light escapes from the far side of the prism.

II.5) When light does escape, is the angle it is **hitting the far side of the prism (**not the angle it is entering the prism) larger or smaller than when it is totally reflected?

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The Science of Light
Session 11
Light Sources - 1

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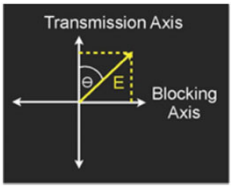
Analyzing Polarization

The transmission of light through a polarizer depends on angle between the direction of oscillation of the polarized light and the transmission axis.

The light that is ***perpendicular*** to the transmission axis (sin Θ) will be ***extinguished*** and the component ***parallel*** (cos Θ) will be ***transmitted***.



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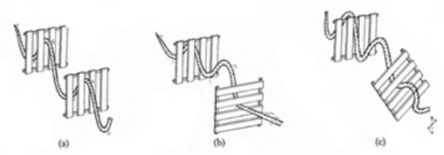
Polarization Filters

Think of light polarization like waves on a rope.

A polarization filter is a fence through which we put the rope

• If two fences (filters) are used, the final wave on the rope will depend on the angular orientation of the fences

- The second polarizer is called the analyzer



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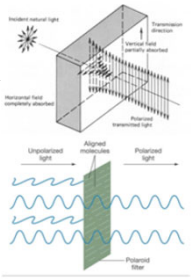
Polarization by Absorption

Some materials preferentially absorb light that oscillates in ONLY one direction

• These materials have an axis of transmission and an axis of absorption

• Used for polarization filters in cameras, sunglasses, LCD displays and other applications



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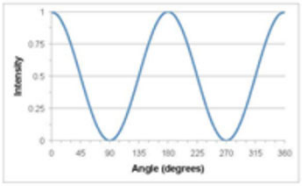
Malus' Law

For two polarizers with unpolarized light shining on the first, this is summarized as **Malus' Law**:

$$I = I_0 \cos^2 \theta$$

where **I** is the intensity of the light that comes through. $\mathbf{I_0}$ is the light that is shining on the first polarizer, and **Θ** is the angle between the two polarizers.



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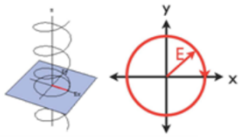
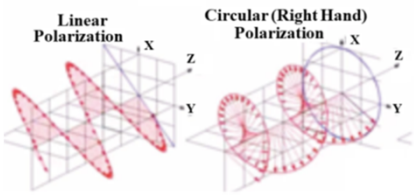
Circular Polarization

In circularly polarized light, the polarization vector rotates in a circle.

The polarization traces out a spiral as it propagates.





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The Science of Light
Session 11
"Pop Quiz"
Light Sources - 1

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In Class Quiz!

Q1: Most natural light is:

A) Unpolarized
B) Vertically polarized
C) Circularly polarized
D) A combination of all 3?

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In Class Quiz!

Q1: Most natural light is:

ANSWER:

A) Unpolarized
B) Vertically polarized
C) Circularly polarized
D) A combination of all 3?

Unpolarized light has no defined direction of polarization. Unpolarized light is represented by two equal, perpendicular polarization vectors. These trace the path of the electric field of the light (electromagnetic) wave…

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In Class Quiz!

Q2: What is polarized light?

A) Light wave, traveling in a particular direction.
B) Electric field, oscillating in a particular direction.
C) Oscillating stream of electrons & magnetons.
D) All of the above

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In Class Quiz!

Q2: What is polarized light?

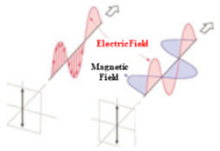
ANSWER

A) Light wave, traveling in a particular direction.

B) Electric field, oscillating in a particular direction.

C) Oscillating stream of electrons & magnetons.
D) All of the above

The polarization of light describes the direction of oscillation of its electric field.
Linear polarized light is represented by one polarization vector that traces the tip of the E-field.



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In Class Quiz!

Q3: What is linear polarization?

A) The electric field only oscillates vertically.
B) The electric field only oscillates diagonally.
C) The ray of light travels straight.
D) None of the above

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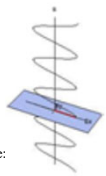
In Class Quiz!

Q3: What is linear polarization?

ANSWER

A) The electric field only oscillates vertically.
B) The electric field only oscillates diagonally.
C) The ray of light travels straight.
D) None of the above

Polarized light can oscillate along any axis.
For example:
A light ray travels along z-direction,
it can be polarized along any line parallel to the x-y plane:



Unpolarized light can oscillate along any axis.

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In Class Quiz!

Q4: What is circular polarization?

A) Two simultaneous electric fields .
B) A simultaneous electric and magnetic.
C) Two perpendicular electric fields.
D) Two electric fields out of sync.

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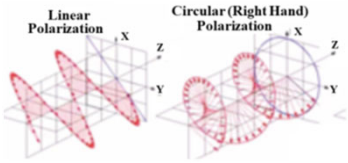
In Class Quiz!

Q4: What is circular polarization?

ANSWER

A) Two simultaneous electric fields .
B) A simultaneous electric and magnetic.
C) Two perpendicular electric fields.
D) Two electric fields out of sync.

Circular light is **perpendicular, linearly polarized light**, of equal amplitudes, that are 90° out of phase



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Questions?

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In Our Next Class #12:

Session 12 ***(11/16 Mon; 11/17 Tues)***
- ***Review of Homework Assignment #12***
- ***Lecture: Light Sources - 2***
- ***In-class problem solving & Review of Example Final Project***

Session 13 ***(11/23 Mon; 11/24 Tues)***
- ***Review of Homework Assignment #13***
- ***Lecture: Optical Devices***
- ***In-class problem solving & Review of Example Final Project***

FINAL EXAM – Sunday 11/29

Session 14 ***(11/30 Mon; 12/01 Tues)***
- ***DUE: Final Project Materials***
- ***Review: Final Exam***
- ***Lecture: Optical Devices and Technology***
- ***In-class problem solving & Review of Example Final Project***

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Any Questions?
Send me an email …

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or
c.rubenstein@ieee.org

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End

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