Pratt

MSCI220C – Fall 2021
The Science of Light

Charles Rubenstein, Ph. D.
Professor of Engineering & Information Science
Materials Courtesy of Dr. Mark Rosin

Session 10 - *VIA REMOTE LEARNING*
Tuesday 11/16/21 2:00pm - 4:50pm
Revision 1

Not Permitted in Class

Be sure to have all cellphones **OFF**
(unless used as calculator…)
Although NOT required
please turn on your cameras

In Today's Class:

Assignments now DUE by 12:00Noon ET MONDAYS!!!

- ***DUE by 12:00Noon ET MONDAY: Homework #10 Summaries (*)***
- ***Lecture: Polarization***
- ***Review: Homework Assignment #10, Example Final Project***

For class Session 11 (11/23):
- ***DUE by 12:00Noon ET MONDAY: Homework #11 Summaries (*)***
- ***Lecture: Light Sources – Part 1***
- ***Review: Homework Assignment #11, Example Final Project***
- ***Research Paper Comments Returned***

For class Session 12 (11/30):
DUE by 12:00Noon ET MONDAY:
Research Paper and Homework #12 Summaries (*) – LAST HOMEWORK!
Lecture: Light Sources – Part 2
Review: Homework Assignment #12, Example Final Project

For class Session 13 (12/7):
DUE by 12:00Noon ET MONDAY: Final Project Paper and PowerPoint Presentation
Lecture: Optical Devices
Review: Example Final Project

For class Session 14 (12/14):
Final Exam – In Class – Emailed by 2:00pm, Due back by 6:00pm

(*) NOTE: Homework Summary must be emailed as a file named: lastname_hwk0#.docx, etc.)

Instructor Contact Information

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

Fall 2021 Office hours: Thursdays
10:00am – 1:00pm
Meeting ID: 569 176 2059
Passcode: Office

BY APPOINTMENT ONLY:
Send me an email … crubenst@pratt.edu
Subject line: **220 Office hour** or **SciLight Office Hour**

21 Fall Class Roster : 220C-01 (2pm)

MSCI220C – 01 Science of Light

Last Name	First Name	Call Me	Time Zone
Chen	Yirong	**EDWARD**	**"+12"**
Fu	Yihan	**HEDY**	**"+12"**
Jeong	Doyool	**LEO**	**ET**
Kahn	Ilianna	**ILLIANNA**	**ET**
Kirby	Ava	**AVA**	**ET**
Li	Xiaokun	**BROOK**	**"+12"**
Lim	Peter	**PETER**	**ET**
Patterson	Evan	**EVAN**	**ET**
Rachford	Flynn	**FLYNN**	**ET**
Yu	Hancheng	**HANGCHENG**	**ET**
Yu	Tianhao	**"T"**	**ET**

Final Schedule: MSCI220C– Fall 2021 – ONLINE

Tues	Notes
8/31	1. Introduction: Introduction to Waves and Light
9/7*	NO CLASS SESSION – Instructor's Religious Holiday
9/14	2. Ray Tracing
9/21	3. Reflection & Curved Mirrors; *H3; Research Paper Topics Due (*)*
9/28	4. Snell's Law and Lenses; *H4; Paper Proposal Returned with Comments*
10/5	5. Photography and the Eye - 1; *H5; Paper Presentation; Project Proposal Due*
10/12*	NO CLASS SESSION – Pratt Midterm Break
10/19	6. Photography and the Eye – 2; *H6; Project Proposal Returned with Comments*
10/26	7. Color in Nature – 1; *Midterm Review;H7; Midterm Exam 10/24*
11/2	8. Color in Nature - 2; *H8; Project Update Due 11/1*
11/9	9. Color Vision; *H9; Research Paper Draft 11/8*
11/16	10. Polarization; *H10*
11/23	11. Light Sources - 1; *H11; Research Paper Comments Returned*
11/30	12. Light Sources – 2; *H12; Research Paper Due 11/29 (last homework)*
12/7	13. Optical Devices; *Final Project Paper/PPT Presentation Due 12/6*
12/14	14. *Final Exam – During Regular Class time – Return by 6:00pm*

(*) Assignments are ALL due by 12:00pm Noon MONDAY before class

About the
Class Session Archives
are updated currently on:
www.CharlesRubenstein.com/220

They are hopefully posted on CANVAS as well in the next weeks…

www.CharlesRubenstein.com/220

Class Sessions: **Available by the Thursday evening after class*

21fa10.pdf = *This slide set**

21fa10_h.pdf = *slide set as handouts**

/01 Week Folder through **/13 Week Folder:**

SEE NEXT SLIDE for Homework Summary requirements…

About the Homework Summaries…

Week 01 through **Week 13 Website Subdirectories (*and shortly, in Canvas Modules*):**

All contain homework, required and optional readings due each week

You are required to submit a summaries of one paragraph for EACH of your observations for all required AND optional reading/video/etc.

are due, not later than 12:00pmNoon ET the MONDAY before class, as a document file or pdf – NO PICTURES or CLOUD DRIVE LINKS!

Filename convention is:

lastname_hwk##.docx *(or **rtf, doc, pdf,** etc.)*

About Emailing me your Assignment

Assignments are due not later than 12:00pm Noon ET on the Monday before each class.

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_paperTopic.docx** (etc.),*
Save your project presentation, etc., files as
***lastname_projectTopic.docx** (etc.),*
***lastname_project.pptx** (etc.),*

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

Your Grade in Science of Light

Midterm Exam (20%)
Final Exam* (20%)
Research Paper (20%)
Final Project (30%)
Homework Summaries (10%)

(*) Final Exam will be given DURING CLASS as noted on the next slide …

About Emailing me your Final Exam

The Final Exam will be emailed to you not later than 2:00pm ET and is due not later than 6:00pm on Tuesday 14 December

*Use **DARK, BLACK pencil or pen**.*
If I can't read your work you get a ZERO!
*2. Please **scan your work** as a PDF and save it as*
lastname_Final.pdf

HOWEVER – IF YOU CAN NOT SCAN –

a. *Take photo(s) of your work and insert the photo(s) into a Word (**docx, doc, or rtf**) document*
b. *Save as **lastname_Final.docx** (etc.)*

Then email your file** to me: **crubenst@pratt.edu
*With the subject line **SciLight Exam**.*
Email me BOTH the worked out problems AND the answer sheet.
I will ONLY grade the Question Paper - Be sure to include any units…

MAKE SURE THAT I CAN PRINT YOUR FILE!!!

Questions?

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MSCI220 Research Paper

RESEARCH PAPER: (20%)

A three-page Paper on *a Science of Light topic, 'device' or piece of optical equipment covered in the course syllabus. AND a one-page bibliography*

ALL SUBMISSIONS ARE DUE NOT LATER THAN 12:00pmNoon ET…

Paper Topic Due (5%): Tuesday 21 September
Returned with my Comments: Tuesday 28 September
Part of Project 'Presentations' Monday 4 October

Paper DRAFT Due (5%): Monday 8 November
Returned with my Comments: By NEXT WEEK
Final Paper Due (10%): Monday 29 November

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21 Fall – Research Paper Topics

MSCI220C – 01 Science of Light

Last Name	First Name	Call Me	Topic
Chen	Yirong	EDWARD	Dispersion of Light
Fu	Yihan	HEDY	Polaroid Camera
Jeong	Doyool	LEO	Depth of Field
Kahn	Ilianna	ILLIANNA	Afterimages
Kirby	Ava	AVA	Moire Effect
Li	Xiaokun	BROOK	Computer Monitors and Color
Lim	Peter	PETER	Parabolic Mirrors
Patterson	Evan	EVAN	Color Blindness
Rachford	Flynn	FLYNN	Mirages
Yu	Hancheng	HANGCHENG	Eyeglasses
Yu	Tianhao	"T"	Mirages

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Questions?

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Final Project – Worth 30%

Midterm' Proposal (10%: 5% proposal, 5% presentation)
Final Project (20%: 5% proposal update, 15% presentation)

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

A one-page 'proposal' overview of the proposed project will be reviewed by the instructor.
'Midterm' Proposal Due (5%): Monday 4 October
Midterm Presentation (5%): In Class 5 October

Your Final Project must be presented as a Paper overview and in PowerPoint.
Topic Proposal Update Due (5%): Monday 8 November
Final Project (15%): Monday 6 December

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Questions?

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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

Questions?

The Science of Light

Session 10
Polarization

The Science of Light

Session 10
Lab Exercises
to do this week – DUE NEXT WEEK with your Homework Summaries
You should have already done the Hologram Exercise…

The Science of Light

Session 10
Color of Light
Lab Exercise I
to do this week – DUE NEXT WEEK with your Homework Summaries

Color of Light Exercise – Page 1

Equipment Required:

Cyan, Magenta and Yellow paints (any type)
Red Filter
Red, Green, Blue Laser Pointers
(OPTIONAL: a Water bottle and (if easily available) powdered milk

Part 1: Creating a Red-Green-Blue 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 at all possible.
TO DO #1: *Snap a picture! Spin the wheel – Do you see more colors?*

(Do the following exercises at home this week and provide the "To Do" question answersas part of your Homework Summaries)

Color of Light Exercise – Page 2

Part 2: 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 previous slide).

TO DO #2: *Snap a picture!*

Part 3. Additive Color Mixing

a. Use the laser pointers to combine the three colors of light from the lasers.
b. Try all the two-color combinations: RG, RB, and GB.
c. Now try all three: RGB, to try to get CMY and white.

TO DO #3: *Snap a picture of each combination!*

Color of Light Exercise – Page 3

Part 4. 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 a bright red light.
c. Now, shine the **red light** from the smartphone + filter onto your color wheel.

TO DO #4: *What color is the **green paint,** and does it match your prediction?*

Part 5. 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 #5.1: *Which color travels further in milky water?*
TO DO #5.2: *Which is scattered away through the sides of the bottle?*

We'll discuss the answers to this Lab exercise in the next class.

The Science of Light

Session 10
Prisms & Lasers
Lab Exercise II

to do this week – DUE NEXT WEEK
with your Homework Summaries

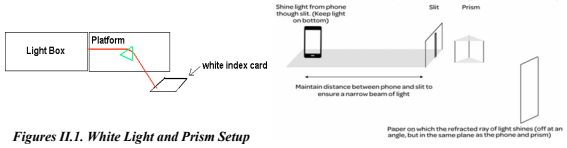
Prisms Exercise II – Page 1

II) Prisms and Spectrums Lab – LIGHT BOX & LASERS

There are a number of light sources you can use for this lab. The sun (*go outside*), 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.

II.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:



Figures II.1. White Light and Prism Setup

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

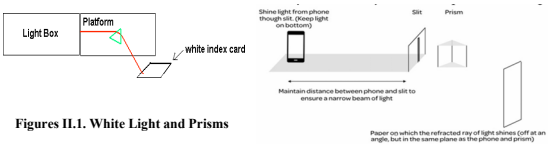
Hold a piece of white paper or white index card at least a half a meter away and observe the light striking the card.

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?

Prisms Exercise – Page 2

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



Figures II.1. White Light and Prisms

II.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?

II.3) 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 laser bends more? Any guesses why?

Prisms Exercise – Page 3

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

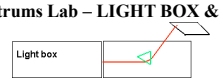
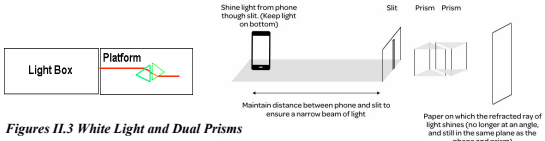


Figure II. 2. White Light and Reversed Prism

II.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?

II.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?



Figures II.3 White Light and Dual Prisms

The Science of Light

Session 10
Total Internal Reflection Lab Exercise III

to do this week – DUE NEXT WEEK
with your Homework Summaries

Total Internal Reflection Lab III – Page 1

III) Total Internal Reflection Lab – Light Box

III.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.

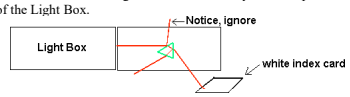


Figure 1. Laser Light and Prism

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.

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

III.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.)

Total Internal Reflection Lab III – Page 2

III) Total Internal Reflection Lab – Light Box - *continued*

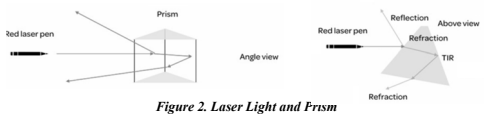


Figure 2. Laser Light and Prism

III.4) Now, be sure you can achieve the configuration above and draw it again below.

III.5) 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.

III.6) 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?

Questions?

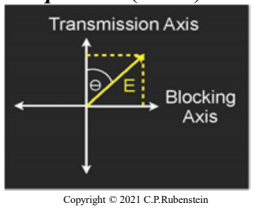
The Science of Light

Session 10
Light Sources - Part 1

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***.



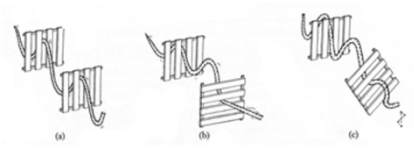
Polarization Filters

Think of light polarization like waves on a rope.

A polarization filter is like a fence through which we put a 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

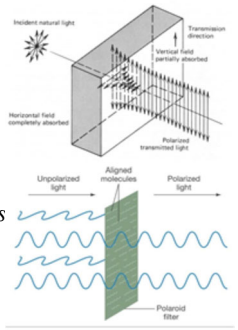


Polarization by Absorption

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

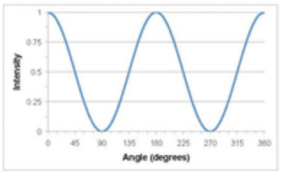


Malus' Law

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

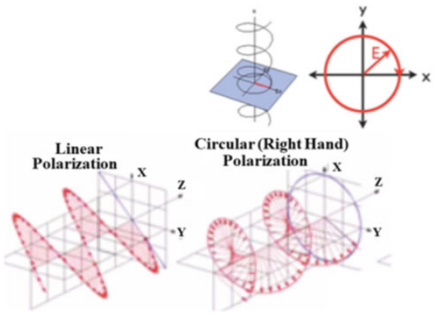
$$I = I_0 \cos^2 \theta$$

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.



Circular Polarization

In circularly polarized light, the polarization vector rotates in a circle tracing out a spiral as it propagates:



Questions?

The Science of Light

Session 10
Light Sources - 1 - Questions

Q1: Most natural light is:

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

We will try to answer this in class before looking at the next slide…

How many think the answer is A? Please raise your hand…

B?

C?

D?

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…

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

We will try to answer this in class before looking at the next slide…

How many think the answer is A? Please raise your hand…

B?

C?

D?

Q2: What is polarized light?

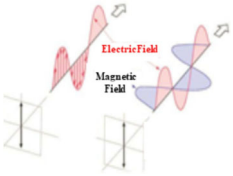
ANSWER

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.



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

We will try to answer this in class before looking at the next slide…

How many think the answer is A? Please raise your hand…

B?

C?

D?

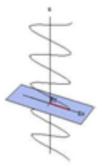
Q3: What is linear polarization?

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.

Q4: What is circular polarization?

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

We will try to answer this in class before looking at the next slide…

How many think the answer is A? Please raise your hand…

B?

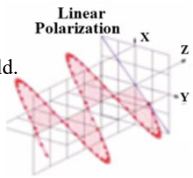
C?

D?

Q4: What is circular polarization?

ANSWER

A) Two simultaneous electric fields.
B) A simultaneous electric and magnetic field.
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

Questions?

In Our Next Class #11:

Assignments DUE by 12:00Noon ET MONDAYS!!!

For class Session 11 (11/23):
DUE by 12:00Noon ET MONDAY: Homework #11 Summaries (*) and Lab Exercise Summaries and sketches
Lecture: Light Sources – Part 1
Review: Homework Assignment #11, Example Final Project
I will have returned your Paper with my comments by end of next week…

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The Science of Light

Any Questions?
Send me an email …

crubenst@pratt.edu

End

