Where: WEB 1460
When: Tues/Thurs 12:25 - 13:45

Office Hours: None (Email me: rmenon@eng.utah.edu)

Textbook: Class notes, reading material & online resources will be provided.

http://lons.utah.edu/
Optics (Science & engineering of light) applied to efficient Generation & Utilization of energy

Learning Objectives:
* Execute a project, where we apply what we learn & hopefully learn more
* Become familiar with the fundamentals of optical design & engineering
* Be aware of emerging technologies in the horizon
Topics of interest

Optical Design (non-imaging optics)

Thermodynamics of solar-thermal & photovoltaic devices

Novel approaches to light management in photovoltaic devices

Emerging areas of relevant technology
Grading

Team-based projects

50% Five Mini-reports (3 pages each)

10% Mid-semester presentation

20% Submission to National Clean Energy Business Plan Competition

20% Class quizzes
Projects

- 3 students/team

Project topics

Project Deliverables

National Clean Energy Business Plan Competition

Mid-semester presentations
Project Topics

solar cooker
solar water pasteurization
solar water desalination
solar refrigeration
Daylighting
solar water-heating
Photovoltaics

Emphasis on the developing world

Cost
Durability
Storage (space requirements)
Cultural factors
Ease of use
Climate conditions

Others (you propose).
Project Deliverables (~3 pages each)

Mini-report 1: Literature Review; Discuss pros, cons, comparisons, overview of existing technologies. Due 09/13/2012


Mini-report 5: Business Plan, Commercialization strategy. Due 12/06/2012

Deadlines are important! 10% of points docked for each day you are late.
National Clean Energy Business Plan Competition


* Regional Competition: CU Cleantech New Venture Challenge (http://nvc.cucleantech.org)
  - Submission materials:
    - Executive Summary (2 pages): Opportunity, go-to-market strategy, market & industry analysis, technical product description, risks, economics & team.
    - 5-minute Video pitch: Be creative. Can be product demo, elevator pitch, slide presentation, etc.
    - IP declaration: Note any intellectual property that you think can be patented.

* First-round winners present in Boulder, CO. Monetary prizes & support from National Renewable Energy Laboratory.
# Course Schedule

**Tentative Schedule for ECE 5962/6961 Optics for Energy. Fall 2012**

<table>
<thead>
<tr>
<th>Date</th>
<th>Week</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/21</td>
<td>Week #1</td>
<td>Overview of course; Intro to project topics</td>
</tr>
<tr>
<td>8/23</td>
<td>Week #1</td>
<td>Introduction to project topics</td>
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<tr>
<td>8/28</td>
<td>Week #2</td>
<td>Solar Radiation: The basics</td>
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<tr>
<td>8/30</td>
<td>Week #2</td>
<td>Thermodynamics of solar heating &amp; cooking</td>
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<tr>
<td>9/4</td>
<td>Week #3</td>
<td>Introduction to Geometrical Optics</td>
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<tr>
<td>9/6</td>
<td>Week #3</td>
<td>Optical design for recycling</td>
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<tr>
<td>9/11</td>
<td>Week #4</td>
<td>Lagrangian &amp; Hamiltonian Optics</td>
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<tr>
<td>9/13</td>
<td>Week #4</td>
<td>Rays &amp; Wavefronts</td>
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<tr>
<td>9/18</td>
<td>Week #5</td>
<td>Light tools optical design software tutorial (Guest lecture: Dr. Mohit Diwekar)</td>
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<tr>
<td>9/20</td>
<td>Week #5</td>
<td>Technology Commercialization (Guest lecture: Frank Noeris, TCO UofU)</td>
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<tr>
<td>9/25</td>
<td>Week #6</td>
<td>[No Class]</td>
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<tr>
<td>9/27</td>
<td>Week #6</td>
<td>Reflection &amp; Refraction</td>
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<tr>
<td>10/2</td>
<td>Week #7</td>
<td>Symmetry</td>
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<tr>
<td>10/4</td>
<td>Week #7</td>
<td>Etendue in phase space [Your idea section due]</td>
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<tr>
<td>10/9, 10/11</td>
<td>Week #8</td>
<td>Fall Break</td>
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## Course Schedule

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<thead>
<tr>
<th>Date</th>
<th>Week</th>
<th>Topic</th>
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<tbody>
<tr>
<td>10/16</td>
<td>Week #9</td>
<td>Review of solar cells (Guest lecture, tentative)</td>
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<tr>
<td>10/18</td>
<td>Week #9</td>
<td>[No Class]</td>
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<tr>
<td>10/23</td>
<td>Week #10</td>
<td>Radiometry, Photometry, Radiation heat transfer</td>
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<tr>
<td>10/25</td>
<td>Week #10</td>
<td>Fundamental concepts of Non-imaging optics</td>
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<tr>
<td></td>
<td></td>
<td>[Project plan section due]</td>
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<tr>
<td>10/30</td>
<td>Week #11</td>
<td>Fundamental concepts of Non-imaging optics</td>
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<tr>
<td>11/1</td>
<td>Week #11</td>
<td>Mid-term project presentations</td>
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<tr>
<td>11/6</td>
<td>Week #12</td>
<td>Statistical Ray Optics</td>
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<tr>
<td>11/8</td>
<td>Week #12</td>
<td>Light trapping</td>
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<tr>
<td>11/13</td>
<td>Week #13</td>
<td>Light trapping – Plasmonics &amp; Dielectric scatterers</td>
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<td>(Guest lecture: Dr. James Nagel)</td>
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<tr>
<td>11/15</td>
<td>Week #13</td>
<td>Light trapping (guest lecture Dr. James Nagel)</td>
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<td>11/20</td>
<td>Week #14</td>
<td>Design of 2D concentrators [Build-out / simulation section due]</td>
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<td>11/22</td>
<td>Week #14</td>
<td>Thanksgiving break</td>
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<tr>
<td>11/27</td>
<td>Week #15</td>
<td>Spectrum splitting approaches</td>
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<tr>
<td>11/29</td>
<td>Week #15</td>
<td>Anti-reflection coatings [Business Plan / Commercialization section due]</td>
</tr>
<tr>
<td>12/4</td>
<td>Week #16</td>
<td>Concentrated Photovoltaics</td>
</tr>
<tr>
<td>12/6</td>
<td>Week #16</td>
<td>Solar Simulators [National Clean Energy Business Plan Application due]</td>
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Why technologies for the developing world?

- Abundant solar resources with little access to infra-structure (electric grid, roads, etc.).
- Biomass resources are fast depleting & also contribute to CO2 emissions.
- Huge impact possible: ~ 1 out of every 4 people have no access to electricity.
- Market Opportunity to build sustainable technological solutions.
Solar Box Cooker

Inner box enclosed in clear glass/plastic
Simple construction
Reflector
Insulation
Slow, even cooking
Safe & easy to use
Panel Cooker

Parabolic Cooker

Higher temperatures possible
Cooks quickly
Needs sun-tracking
More complex & expensive
Risk of fires & eye injury
Fresnel Lens Cooker

Higher temperatures possible
Cooks quickly
Needs sun-tracking
More complex & expensive
Risk of fires & eye injury
Heat Principles

Heat passes through a hot rock by dark pot, which heats the glass. Which wavelengths, which box will receive more sunlight? Which box has more losses?
Heat Gain: Greenhouse effect

Visible light passes through glass. Absorbed by dark pot, which re-radiates at longer wavelengths, which are trapped inside. The absorbed energy must be conducted to the food efficiently.

Figure 2. The greenhouse effect
Heat Gain: Glass orientation

Which box will receive more sunlight?
Which box has more losses?

Figure 3. Glass orientation
Heat Gain: Reflectors

Reflectors can increase effective light capture area (aperture).

Figure 4. Reflectors for additional solar gain
Heat Loss: Conduction, Radiation & Convection

Figure 6. Heat radiates from warm cookware.

- Absorber plate insulated from bottom of cooker.
- Radiant heat (longer wavelength) trapped by container (glass, foil, etc.)
- Heated air may leak through gaps, doors (convection).
Heat Storage

- Thermal mass is the ability to retain heat.
- Higher thermal mass takes longer to heat up.

Figure 8. Thermal mass inside of the solar box.
Materials Requirements

- Structural materials: wood, cardboard, metals, bamboo, bricks, stone, plastic, rattan, etc.
- Insulation: al foil, down feathers, cellulose, rice hulls, wool, etc.
- Transparent material: glass, high-temp plastics (oven roasting bags), etc.
- Moisture resistance: inner walls must protect the rest of the cooer from moisture.
Structural materials
wood, cardboard, metals, bamboo, bricks, stone, plastic, rattan, etc.

Insulation
Al foil, down feathers, cellulose, rice hulls, wool, etc.

Transparent material
glass, high-temp plastics (oven roasting bags), etc.

Moisture resistance
Inner walls must protect the rest of the cooker from moisture.
Other design considerations

Size
- Appropriate for amount of food.
- Portability needs.
- Cookware accommodation.

Sunlight collection area
- Larger collection area → higher temperature
- As long as heat loss is not increased

Solar cooker proportion
- Is a square box better than a rectangular box?
- Which direction should the rectangular box be oriented?
- Is tracking required?
Challenges for adoption

- Taste of food
- Temperature control
- What about cloudy days?
- Cost
- Disruption traditional gender roles.

Opportunities for technologists!
New market opportunities as fuel prices rise
Can we combine these technologies with micro-credit?