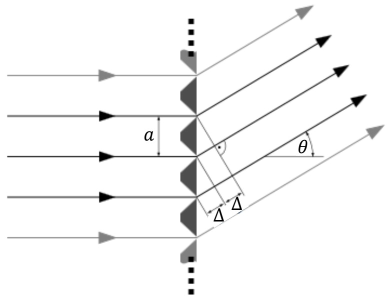
PHY385-H1F Introductory Optics

Last Class!! – Outline:

- Diffraction Gratings
- Things to know about the final exam
- A look ahead: PHY485: "Modern Optics"
- Some Course Review

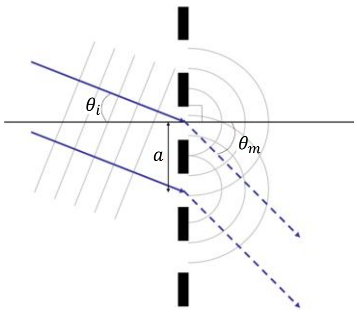
Grating Equation

Bright orders at: $m\lambda = a\sin\theta$



Diffraction Gratings

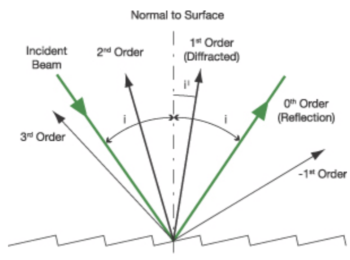
Bright orders at: $m\lambda = a(\sin\theta_m - \sin\theta_i)$



Diffraction Gratings

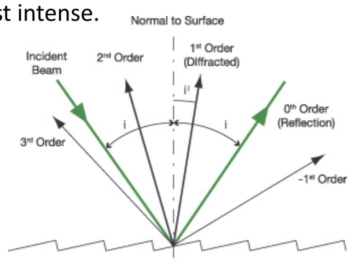
- Reflection gratings obey a similar equation as transmission gratings:

$$m\lambda = a(\sin\theta_m - \sin\theta_i)$$



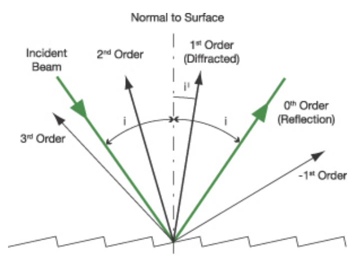
Diffraction Gratings

- The $m = 0$ order corresponds to regular reflection: $\theta_m = \theta_r$: No dispersion.
- Other orders are dispersed: rainbows. Usually the first order lines ($m = 1$ or $m = -1$) are the most intense.



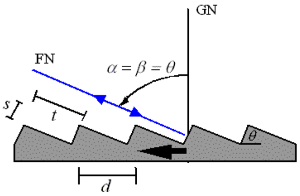
Diffraction Gratings

- The grating below is "blazed", meaning its surface is a reflective saw-tooth shape. Blazing can increase the efficiency for a particular order.
- It appears to be blazed for 1st order

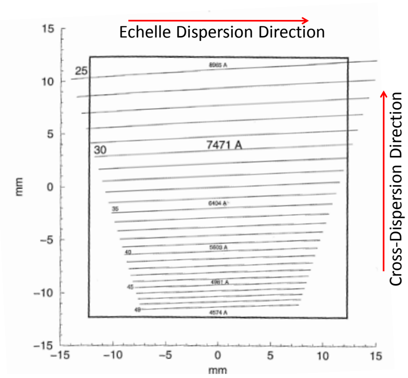


Echelle Gratings

- An echelle grating is blazed for extremely high order. The purpose is to increase dispersion, which is proportional to m.
- In practice, adjacent orders always overlap, so a second "cross-grating" must be used to separate the orders on the detector.



Echelle Spectrum on a CCD detector



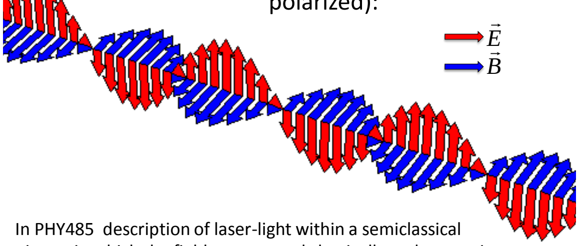
Final Exam

- Thursday Dec. 13 from 2:00 to 4:00pm, in the Exam Centre at 255 McCaul, Room EX320
- First 2 Pages with "helpful information" is posted on the course web-site, under "Materials".
- Allowed aids include a calculator, and up to 2-pages of hand-written notes.
- There are 8 problems, similar to the style you have seen on the mid-terms and Practicals presentation-sessions.
- No multiple choice.
- The material includes the entire course, spread evenly.

PHY1485H-F / 485

- "Lasers and Modern Optics" is a cross-listed course (grad students and undergrads), currently taught by Professor Thywissen. He recommends Hecht 4e.
- Current Pre-requisites are "Electromagnetic Theory" (PHY350) and "Quantum I" (PHY356)
- Topics include:
  - Gaussian beam modes and their relation to optical resonators
  - Fibre and Slab waveguides
  - Laser Cooling
  - Photonic bandgap structures
  - Extreme optics
  - Quantum information
- There are End-of-year student seminars.

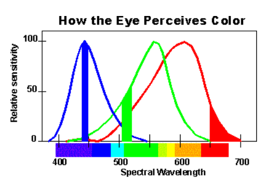
An Electromagnetic Wave (linearly polarized):

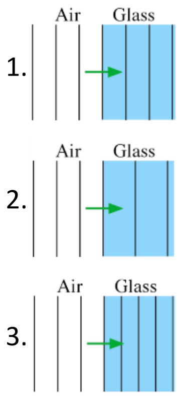


In PHY485 description of laser-light within a semiclassical picture in which the fields are treated classically and matter is treated quantum mechanically.

Some Review… Visible Light

- Hecht says: 455 to 780 nm. Personally, I can't see light beyond about 700 nm. And I am able to see violet down to about 420 nm.

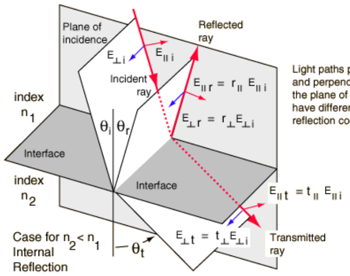


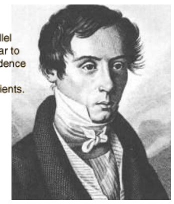


A light wave travels, as a plane wave, from air (n = 1.0) into glass (n = 1.5).

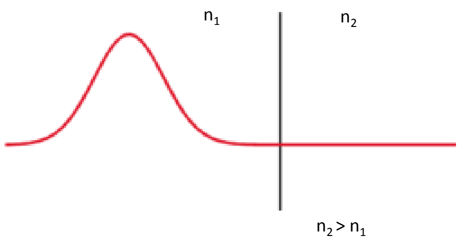
Which diagram shows the correct wave fronts?

- 1814 – **Jean Fresnel** used the idea of polarization to predict amplitudes of reflected and transmitted light from glass interfaces.

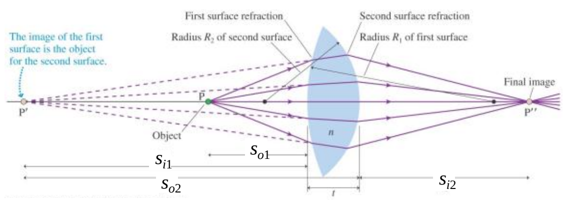




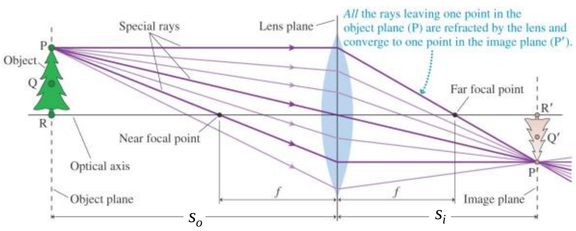
Partial transmission and reflection amplitudes of a wave travelling from a low to high refractive index medium.



Lensmaker's Formula



$$\frac{1}{f} = \frac{n_l - n_m}{n_m}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

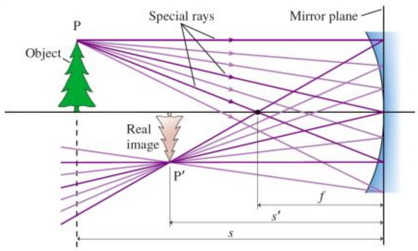


The Thin Lens Equation: $$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$$

f is positive for a converging lens
f is negative for a diverging lens
s_o is positive means object is real, to the left of lens
s_i is positive means image is real, to the right of lens
s_i is negative means image is virtual, to the left of lens

- The total amount of light collected by the lens is proportional to D^2.
- The image area of an extended object is proportional to f^2.
- So the flux density at the image plane varies as $(D/f)^2$.
- D/f is called "relative aperture"
- f/D is called the "f-number" (ie F1.4, F2, F16, etc)
- $(D/f)^2$ is called the "speed". The higher the speed, the shorter an exposure time you need for the same image brightness.
- That's why f-numbers tend to increase by factors of $\sqrt{2}$ on cameras – for each step you have to double the exposure time.

FIGURE 23.52 A real image formed by a concave mirror.



The Mirror Equation

For a spherical mirror with negligible thickness, the object and image distances are related by

$$\frac{1}{s_o}+\frac{1}{s_i}=\frac{1}{f} \qquad \text{(thin-mirror equation)}$$

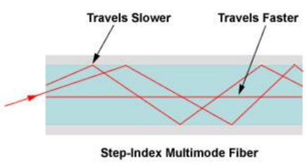
where the focal length *f* is related to the mirror's radius of curvature by

$$f=\frac{R}{2}$$

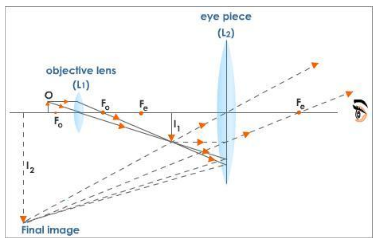
Sign convention for spherical mirrors

	Positive	Negative
R and f	Concave toward the object	Convex toward the object
s_i	Real image, same side as object	Virtual image, opposite side from object

Modal Dispersion In Optical Fibres



Compound Microscope



$$MP=\left(-\frac{16\text{ cm}}{f_o}\right)\left(\frac{25\text{ cm}}{f_e}\right)$$

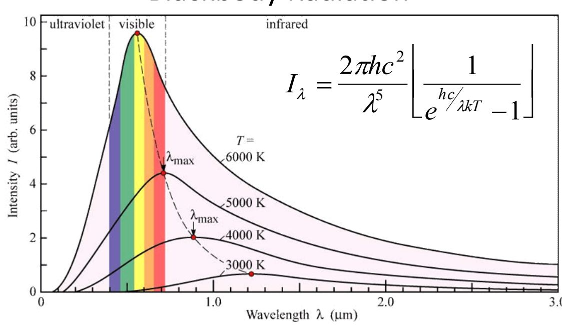
Telescope

- Invented by somebody in Holland (1608), later used by Galileo of Italy (1610).
- Objective forms a real, inverted image in the tube.
- Eyepiece is used as a magnifier to view this image.

Galileo Galilei

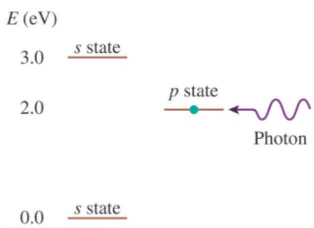
$$MP=\frac{\alpha_a}{\alpha_u}$$

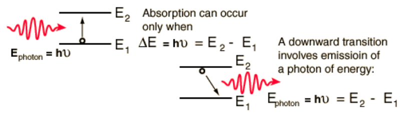
Blackbody Radiation

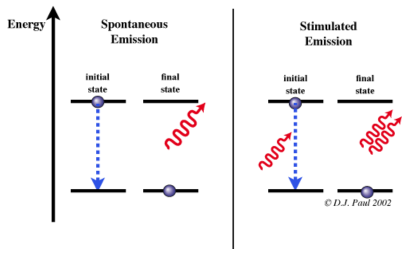


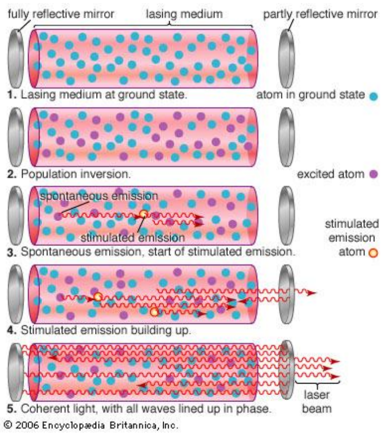
A photon with energy 2.0 eV is incident on an atom that is in the *p* state. Which can happen?

1. Absorption
2. Stimulated emission
3. Spontaneous Emission
4. Either 1 or 2
5. Either 2 or 3

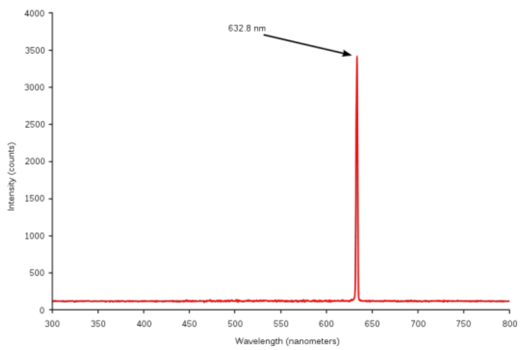








Spectrum of a He-Ne Laser



What best describes "dichroism"?

1. Absorption coefficient depends on the linear polarization state (vertical or horizontal)
2. Absorption coefficient depends on the circular polarization state (L or R)
3. Index of refraction depends on the linear polarization state (vertical or horizontal)
4. Index of refraction depends on the circular polarization state (L or R)

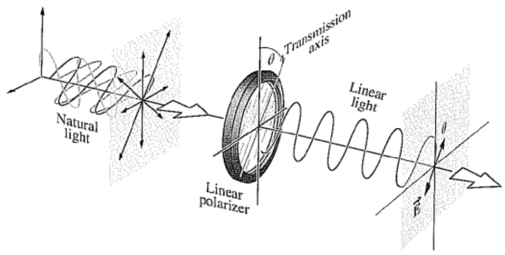
What best describes "birefringence"?

1. Absorption coefficient depends on the linear polarization state (vertical or horizontal)
2. Absorption coefficient depends on the circular polarization state (L or R)
3. Index of refraction depends on the linear polarization state (vertical or horizontal)
4. Index of refraction depends on the circular polarization state (L or R)

What best describes "optical activity"?

1. Absorption coefficient depends on the linear polarization state (vertical or horizontal)
2. Absorption coefficient depends on the circular polarization state (L or R)
3. Index of refraction depends on the linear polarization state (vertical or horizontal)
4. Index of refraction depends on the circular polarization state (L or R)

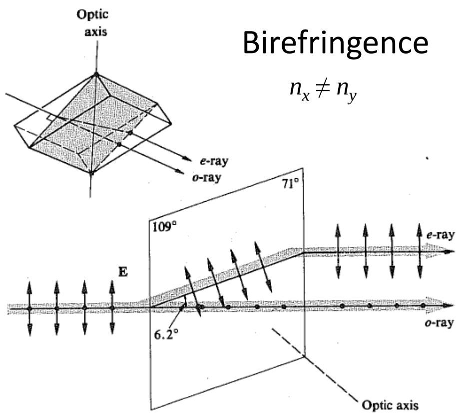
Dichroism



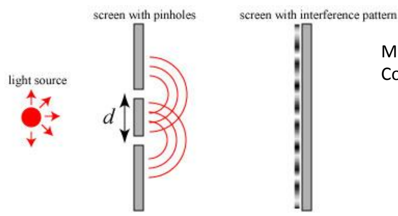
"Unpolarized" light incident on a linear polarizer tilted at an angle θ with respect to the vertical

Birefringence

$n_x \neq n_y$



A Young Double Slit Experiment

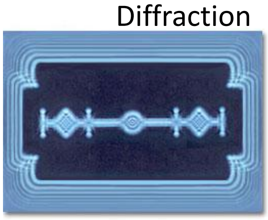


Measures Spatial Coherence

- When d exceeds a critical value, D, the fringes disappear
- D = "Transverse Coherence Length" for this particular light source
- πD^2 is the "Coherence Area"
- Coherence area for filtered sunlight: A ~ 10^{-2} mm^2
- Coherence area for filtered starlight: A ~ 6 m^2

Source: http://skullsinthestars.com/2008/09/03/optics-basics-coherence/

Diffraction



Francesco Grimaldi

- Sometimes light does not travel in straight lines, or rays. The rays bend around edges, because light is actually a wave.
- This was first noted and discussed by Grimaldi in 1640.