Lecture 40 iq35

1. Relationship between energy and momentum for light.

2. Radiative pressure. Reflective case and the absorptive case.

3. Polarization of EM waves.

   - Parallel metal strips. Define the transmission axis.
   - The ratio between the transmitted intensity and the initial intensity.
   - The metal strip analyzer and the un-polarized light

4. The magnetic force due to an em waves exerts on q which is initially at rest.

5. Why the sky is blue and the light is polarized?

   - The setup.
   - Comparison of the intensities of the rescattered light at two wavelength.

Announcement:

1. The updated course summary of unit 4 has been posted with the date 4/21/13.
   - Since the posted LM covered Malus law, Malus law has been added in the summary.
   - The homework set: Ch24.h5 has been deleted from unit 4 in our updated lesson plan. The course-material on lens has also been removed from the summary.

2. My plan is to cover Sec 24.7 and 24.8 this Friday. Sec 25.1 on Monday. The content of the materials are straightforward please read ahead and do your homework problem.

3. I plan to post review unit4 problems before noon , next Monday

1. Relativistic kinematics: Relationship between energy + mom. for light

For a particle with mass m,

$$\text{Energy} = mc^2\gamma, \quad \gamma = \frac{1}{\sqrt{1-\beta^2}}, \quad \beta = \frac{v}{c}.$$

(γ: Lorentz factor)

$$\text{momentum} = mv\gamma$$

$$\frac{\text{Energy}}{\text{mom}} = \frac{c^2}{v}.$$

Photon - light particle has negligeble mass, $v = c$

$$\frac{U}{p} = \frac{c^2}{v} = c, \quad \therefore p = \frac{U}{c}.$$

2. Radiative pressure: $\text{Pressure} = \frac{F}{A}$

$$F = \frac{\Delta p}{\Delta t}$$

Impact on the medium:

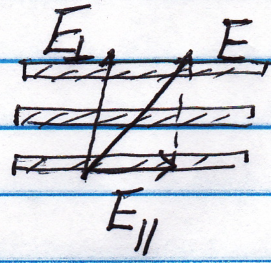
Reflective case: $\Delta p = 2p = 2\frac{U}{c}$ $\Big|$ p_{ins} / p_{an}

Absorptive case: $\Delta p = p = \frac{U}{c}$ $\Big|$ p_{ins}

$$\text{Pressure} = \frac{\frac{\Delta p}{\Delta t}}{A} = \begin{cases} \text{refl.} & \frac{2U/c}{A\Delta t} = \frac{2u}{A\Delta t} = 2u \\ \text{abs.} & u \end{cases}$$

3. Polarization: Direction along oscillation of $\vec{E}$

- Parallel metal strips



Incident polarization is along the arrow. Decompose it into $\perp$ and $\parallel$ components.

$\parallel$ component: Large induced current within the strip. Large energy lost. Transmission suppres

$\perp$ component: Negligible induced current. Negligible energy lost. Allows transmissio

$\perp$ direction here defines transmission axis.

- Intensity ratio:

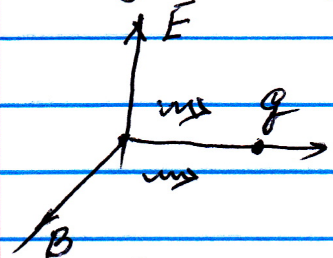
$$\frac{I_{out}}{I_{in}} = \left(\frac{E_\perp}{E_{in}}\right)^2 = \cos^2\alpha \quad \text{--- Malus's Law}$$

where α is the angle between incident polarization + transmission axis.

- Metal strip analyzer:
  - Rotating the sheet can check polarization of the incident light
  - Unpolariz. incident light, if no variation in intensity
  - Unpolarized light may be represented by:

    two equal weight mutually ⊥ polarized lights.
- Two mutually ⊥ analyzer can fully block out an unpolarized light

4 Radiation from a charged particle initially at rest:



$$\langle v \rangle = \langle qE \rangle$$

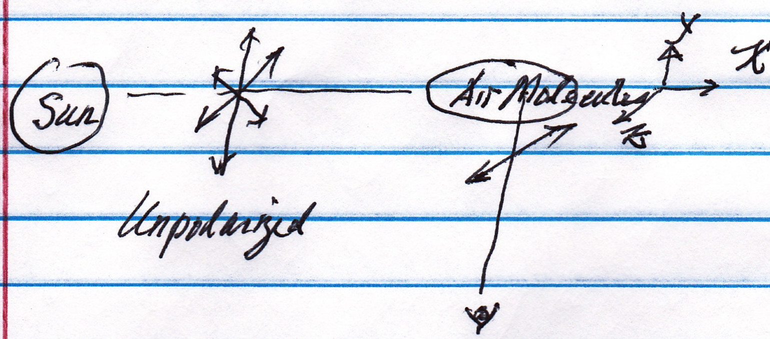
$$\vec{F} = q\vec{v}\times\vec{B}$$

$q>0$ case: $\langle\vec{F}\rangle = \langle q\vec{v}\times\vec{B}\rangle = \langle\vec{v}\times\vec{B}\rangle = \langle\vec{E}\times\vec{B}\rangle$

Dir of magnetic force on q initially at rest

	$q>0$	$q<0$	
1)	Left	Left	Hint: $\vec{F} = q\vec{v}\times\vec{B}$
⇒ 2)	Right	Left	
3)	Left	Right	$\langle\vec{v}\rangle = \langle q\vec{E}\rangle$
⇒ 4)	Right	Right ✓	Notice: $\langle F\rangle = q^2\langle E\times\vec{B}\rangle$!

5. The polarized sky light.



Sun light: Unpolarized light.

Rescattered light viewed by ground observer is polarized along z.

Intensity of rescattered light:

- $I = cu = c(u_E + u_B) = c \cdot 2u_E = c\,\epsilon_0 E^2$, $E \propto a_\perp \propto \omega^2 z$.
- Compare intensity of rescattered light with frequencies ω_1 and ω_2.

$$\frac{I_1}{I_2} = \frac{E_1^2}{E_2^2} = \left(\frac{a_{\perp 1}}{a_{\perp 2}}\right)^2 = \left(\frac{\omega_1^2 z}{\omega_2^2 z}\right)^2 = \left(\frac{\omega_1}{\omega_2}\right)^4 = \left(\frac{\lambda_2}{\lambda_1}\right)^4$$

$$\frac{I_{Blue}}{I_{red}} = \left(\frac{\lambda_r}{\lambda_b}\right)^4, \quad \frac{\lambda_r}{\lambda_b} = \frac{700nm}{400nm} = 1.75, \quad \frac{I_b}{I_r} = (1.75)^4 \sim 9.$$