L30. Polarizers, Malus's Law, Brewster Angle, Polarization by Reflection and Scattering, Why is the sky blue, Why are sunsets red? The sun will set in the lecture hall!

I: light intensity

-Linearly Polarization

Incident Light, Reflected Light, Refracted Light

1. Polarizer (Edwin H. Land, Founder of Polaroid)

$$I_{100\%\ pol} = \overline{\cos^2\theta}\ I_{unpol} = \frac{1}{2} I_{unpol}$$

$I_1 = I_0 \cos^2\theta$ (Malus's Law: polarized light through another polarizer)

2. Polarization by Reflection (Brewster Angle)

$$E_{par_{refl}} = E_{par_{inc}} \frac{n_1 \cos\theta_2 - n_2 \cos\theta 1}{n_1 \cos\theta_2 + n_2 cos\theta_1} = - E_{par} \frac{\tan\left(\theta_1 - \theta_2\right)}{\tan\left(\theta_1 + \theta_2\right)}$$

when $\theta_1 + \theta_2 = 90°$, $E_{par_{refl}} = 0$, t.f. 100% polarized light

$\tan\theta_1 = \frac{n_2}{n_1}$ (θ_1: Brewster Angle)

3. Scattering

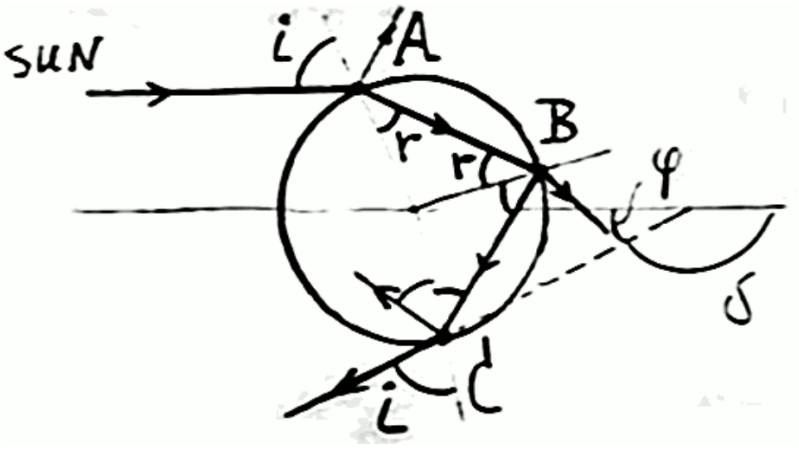
-Probability of scattering 10x higher for blue light than red light (18.03)

Sky blue because of this phenomenon

Sun rise and set are red because they are just above the horizon, light travel through thick atmosphere and blue light has already scattered out

-Demo 46:00: Light gradually be scattered to change from white to yellow to red… (not unlike sunset)

L31. Rainbows (Take Notes); A Modest Rainbow will appear in the lecture hall!; Fog Bows, Supernumerary Bows, Polarization of the Bows, Haloes around the Sun and Moon, Coronae, Glories, Mock Suns (Sun Dogs)



$\delta = 180 + 2i - 4r$

$\delta_{\min} = 138$

$\phi_{\max} = 42$

$\phi_{\max_{blue}} = 40.7 \qquad \phi_{\max_{red}} = 42.4$

L33. Double-Slit Interference, Interferometers

-Interference

-Constructive Interference

$r_2 - r_1 = n\lambda$

$\sin\theta_n = \frac{n\lambda}{d}$

$x_n \approx \frac{Ln\lambda}{d}$ (small angle approximation)

-Destructive Interference

$r_2 - r_1 = (2n+1)\frac{\lambda}{2}$

$$\sin\theta_n = (2n+1)\frac{\lambda}{2d}$$

$$x_n \approx L(2n+1)\frac{\lambda}{2d}$$

-Demo 23:00: Sound Interference

-Demo 38:00: Young's Double-slit Interference Experiment

-Demo 48:00: Radio Wave Interference

L34. Gratings, Resolving Power, Single-Slit Diffraction, Angular Resolution, Human Eye - Telescopes

-Multiple-slit Interference

-Constructive

$$\sin\theta_n \approx \theta_n = \frac{n\lambda}{d}$$ (small angle approximation)

-Deconstructive

$N-1$ minima between each two maxima (N = number of slits)

-Demo 14:00: White light multiple-slit interference —— colored first/second/… order maxima

-Diffraction (Single-slit Interference)

Maximum: $\theta = 0$

Minima: $\sin\theta_n \approx \theta_n = \frac{n\lambda}{a}$ (a: size of opening)

$$x_n \approx \frac{Ln\lambda}{a}$$

-Diffraction Limitation of Angular Resolution

$$\theta_1 = 1.22\frac{\lambda}{a}$$

Rayleigh Criterion of Resolution

L35. Doppler Effect, The Big Bang, Cosmology

-Doppler Shift Equation

$$f' = f\frac{v_{sound} - v_{receiver}}{v_{sound} - v_{transmitter}}$$

used by police car to measure your speed

-Light

$$f' = f\left(\frac{1-\beta}{1+\beta}\right)^{\frac{1}{2}} \quad (\beta = \frac{v_{relative}}{c})$$

$$\lambda' = \lambda\left(\frac{1+\beta}{1-\beta}\right)^{1/2}$$

$\lambda' > \lambda$: red shift receding

$\lambda' < \lambda$: blue shift approaching

-The Big Bang

Nebulae are always receding from us

-Hubble Theory

$$v = Hd \qquad (H_0 = 72\frac{km/\sec}{Mpc} \quad 1Mpc = 3.26\times 10^6 light\ years)$$

$d = vt_{age} \quad \Rightarrow \quad t_{age} = \frac{1}{H} \approx 14$ billion years

-Cosmology

Allen Guth, Scott Hughes and Max Tegmark are the experts in this area