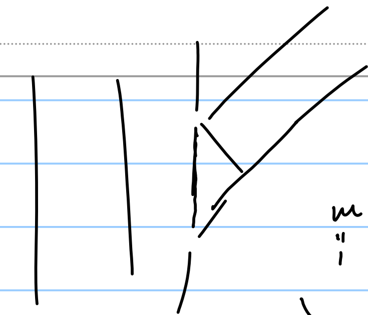
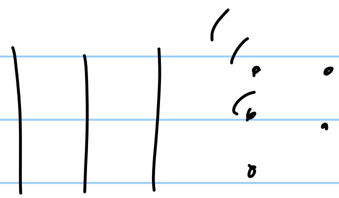
Note Title 8/7/2006

λ spacing



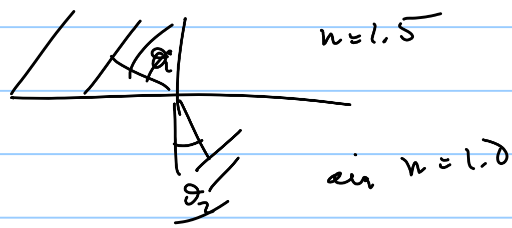
$m\lambda = d \sin\theta$, $m = 1$

$\frac{\lambda}{d} = \sin\theta$



$\frac{6328}{2} = \sin\theta$ 1st order max

tot internal reflection

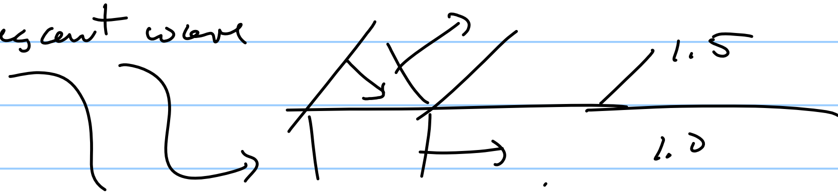


$n_1 \sin\theta_1 = n_2 \sin\theta_2$, $n_2 = 1.0$

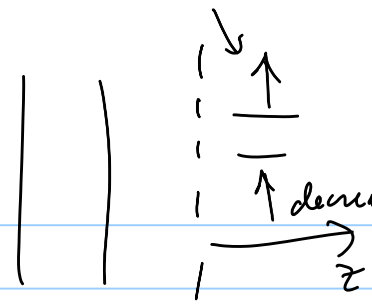
$\sin\theta_2 = \frac{n_1}{n_2} \sin\theta = \frac{1.5}{1.0} \sin\theta$

$\sin\theta_2 = 1.1$

evanescent wave

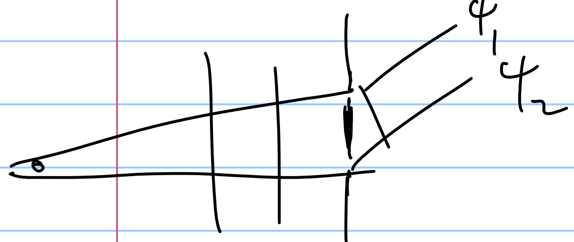


$m\lambda = d\sin\theta$



$\frac{\lambda}{d} > 1$

interference

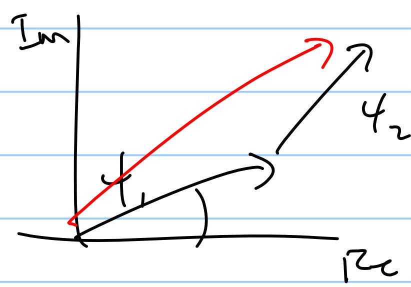


$$\psi_{tot} = \psi_1 + \psi_2$$

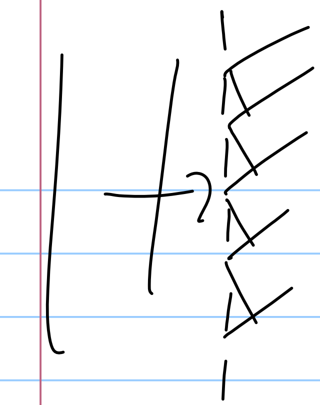
$$\psi_1 = \psi_{01} e^{i\underline{\underline{kr_1}} - \omega t}$$

$$\psi_2 = \psi_{02} e^{i\underline{\underline{kr_2}} - \omega t}$$

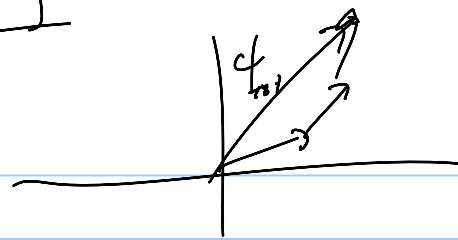
phasors



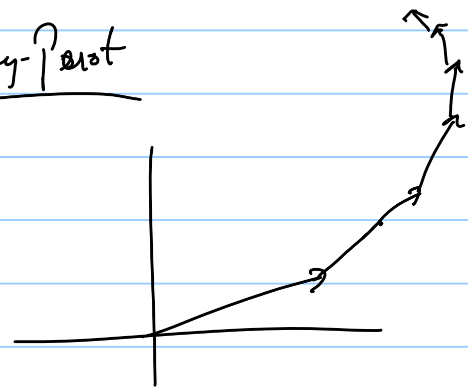
$$\left.\begin{matrix} \mathrm{Re} \\ \mathrm{Im} \end{matrix}\right\} e^{i\varphi}$$



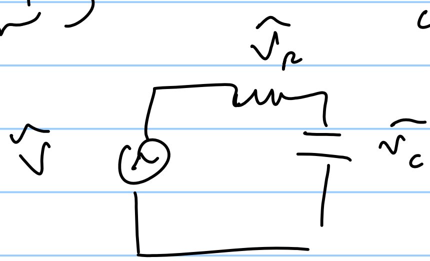
grating

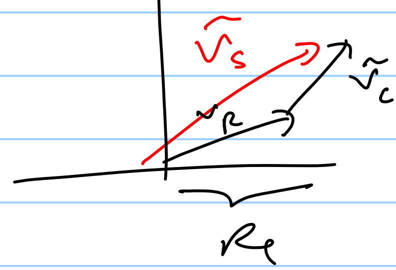


Fabrey-Perot

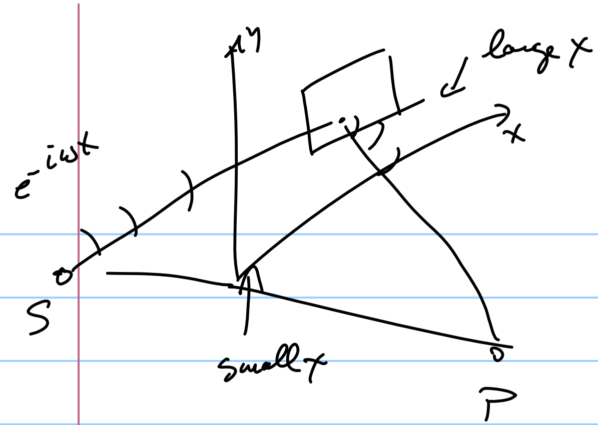


$\cos(-\omega t+\phi_c) \rightarrow e^{i(-\omega t+\phi_c)}$





Fraunhofer $\int e^{iky\sin\theta}\,dy$

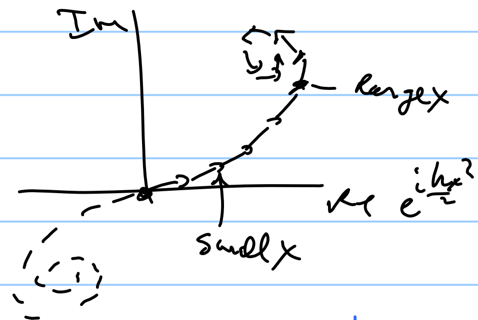


Fresnel $\to \int e^{ik(x^2+y^2)/L}\, dx\, dy$

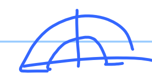
$e^{-i\omega(t-\frac{r}{c})} \to e^{i(kr-\omega t)}$

1 - D $\int_{x_1}^{x_2} \underbrace{e^{i\frac{kx^2}{2}}}_{\text{phasor}} dx$

sum of phasors



ψ_1 wave amplitude to go from source to rec.

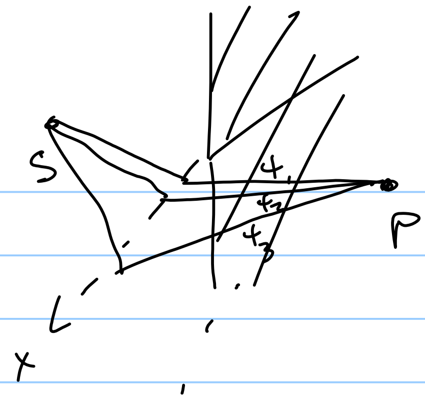


$\vec{A} = \frac{\mu_0}{4\pi}\int \frac{\vec{J}(\vec{r}',t_r)}{r}\, d\tau'$ $J\, d\tau \to I\, d\vec{l}$

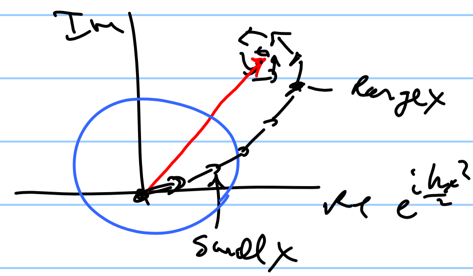
add vector $d\vec{l}$ along path

$d\vec{l} = R\, d\theta\, \hat{\theta}$

$-2R\hat{x}$

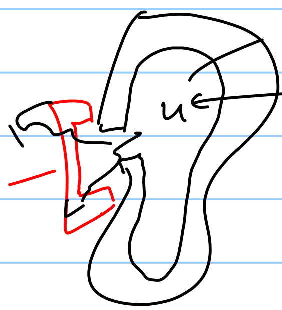


x from 0 to ∞



rec.

Blackbody radiation:



cavity

energy density

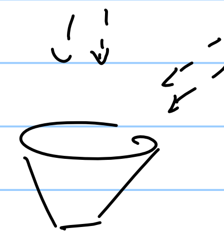
power $\longrightarrow$

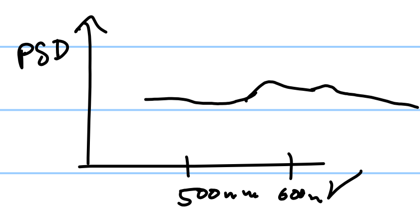
spectral density

Intensity $\frac{\text{Watts}}{m^2}$

$$\int \left(\frac{1}{2}\epsilon_0 E^2 + \frac{1}{2\mu_0} B^2\right) d\tau$$

$$\frac{\text{Watts}}{m^2 \ \text{Hz}}$$





Griffiths $\langle I \rangle = \frac{uc}{2}$ ← energy density c speed of light

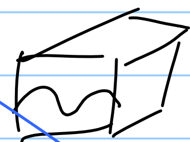
Fowles $I = \frac{uc}{4}$ $\frac{\text{Joules}}{m^3}\,\frac{m}{s} \rightarrow \frac{\text{Joules}}{m^2 s}$

u

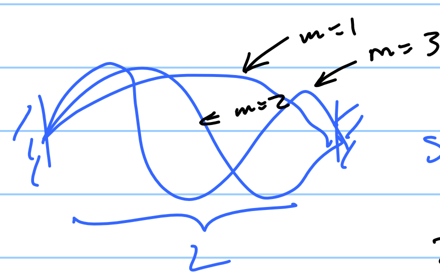
$I_\nu = \frac{u_\nu c}{4}$ need to find this for a blackbody since it is what we measure

↑ power spectral density

modes of EM field in cavity



- each mode has ν
- energy per mode times $\frac{\#\text{ modes}}{\text{freq. interval}} \rightarrow u_\nu$



string

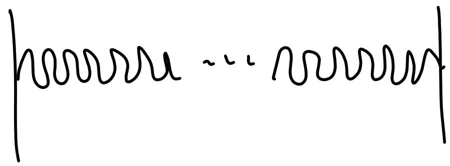
1 λ, 2λ, - -

$2L = m\lambda$ $\lambda\nu = c$

$2L = m\frac{c}{\nu}$ $\nu = m\frac{c}{2L}$ $5\times10^{14} = \nu_{HeNe}$

$L = 1\,m$

$5\times10^{14} = m\frac{c}{2L}$; $m = \frac{5\times10^{14}}{3\times10^{8}}\,2 \approx 3\times10^{6}$



$$\nu = \frac{mc}{2L}$$

$$m = \frac{2L}{c}\nu \qquad dm = \frac{2L}{c}\,d\nu = \frac{2}{3\times 10^{8}}\,10^{13}$$

$$\frac{dm \text{ modes}}{d\nu \text{ Hz}} \rightarrow \frac{dm}{d\nu} = \frac{2L}{c} \quad \text{mode spectral density}$$

$\uparrow$

mode spectral density

$$\underbrace{\text{mode spectral density}}_{\eta_\nu}\ \frac{\text{energy}}{\text{mode}} = \frac{\text{energy}}{\text{Hz}}$$

3-D extension $\qquad$ 1-D $\quad m = \frac{2L}{c}\nu$

3-D $\quad$ # modes $\propto \frac{L^3}{c^3}\nu^3 \rightarrow \frac{8\pi\nu^3}{3c^3}L^3 = N$

mode density $\left(\frac{\text{modes}}{\text{Hz}}\right) = \frac{dN}{d\nu} = \frac{8\pi 3\nu^2 L^3}{3c^3}$

$\frac{\text{mode density}}{\text{vol}} = \frac{8\pi 3\nu^2}{3c^3}$

2 polarization

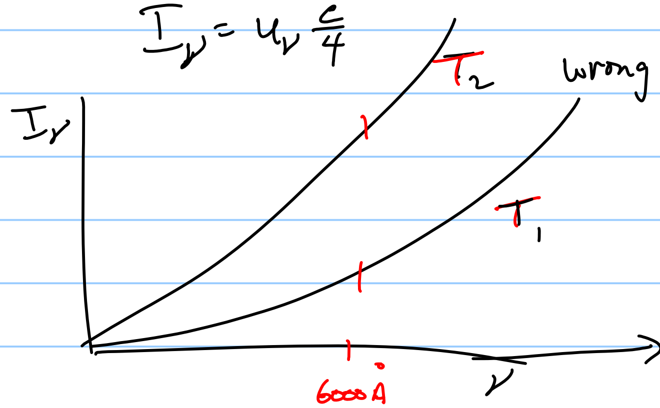
mean energy per mode (degree of freedom) $= \frac{kT}{2} \times 2$

$\frac{8\pi\nu^2}{c^3} kT = u_\nu$

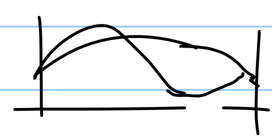
$I_\nu = u_\nu \frac{c}{4}$

modes / Hz

energy/mode



Particles of light, each with energy $h\nu$



each mode has 1 freq

$\nu = \frac{nc}{2L}$

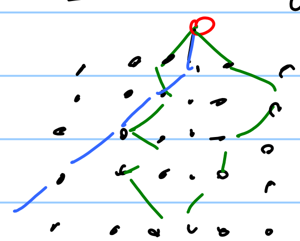
$\langle n_\nu \rangle$ average # of photons/mode with each photon energy $= h\nu$ (not kT/mode)

$$\frac{\text{mean energy}}{\text{mode}} = h\nu \langle n_\nu \rangle$$

$$u_\nu = 8\pi \frac{h\nu^3}{c^3} \langle n_\nu \rangle \qquad I_\nu = 2\pi \frac{h\nu^3}{c^2} \langle n_\nu \rangle$$

fixed EM energy in photons then how do you distribute a given energy into photon in cavity?

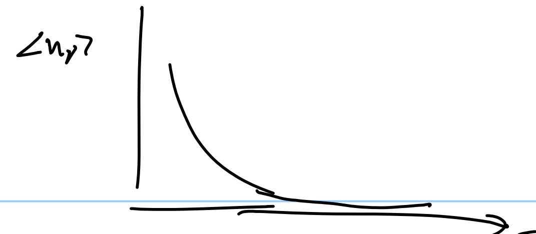
could put lots of photons at low freq ($m = 1$) or just a couple at high freq



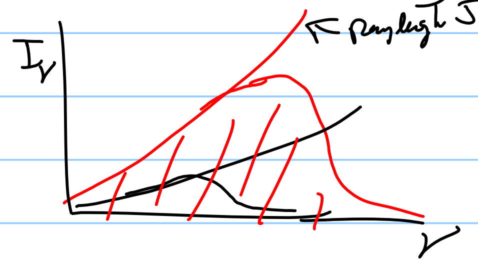
ways something can happen $\propto$ prob of that happening

Dalton Young

$$\langle n_\nu \rangle = \frac{1}{e^{h\nu/kT} - 1}$$



$$I_\nu = \frac{2\pi h \nu^3}{c^2} \underbrace{\frac{1}{e^{h\nu/kT} - 1}}$$



$$I = \int I_\nu \, d\nu = \sigma T^4 = \frac{\text{Power}}{\text{area}}$$ Blackbody

voltage in thermocouple

const

person has a total naked area of 1.4 m^2 & average skin temp of 33°C. How much energy does that person radiate?

absorption

$$\frac{P}{A} = \epsilon \sigma (T^4 - T_e^4) = .97 \; 5.67 \times 10^{-8} \frac{\text{watts}}{m^2 \cdot K} (306^4 - 293^4)$$

not a blackbody

$$= 76.9 \frac{W}{m^2}$$

$76.9 \times 1.4\ m^2 = 108$ Watts