Friday 11:30 am EBC 507

gruntled ?

will cover E & M :)

① Many astro structures give off hella radiation
Earth doesn't give off any where near same

Energy → momentum → force

it's a waiting game, can't get close

what does get here?
cosmic rays
neutrinos ν

radiation processes are well studied unlike neutrino & gravitational wave processes

Spectrum: energy / wavelength

line spectra vs continuum

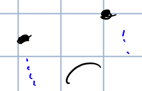
how to generate E & M: quantum mechanics of system & continuum radiation

Lyman series
⋮ series
series

accelerated charges
(not velocities)

purely mechanical process

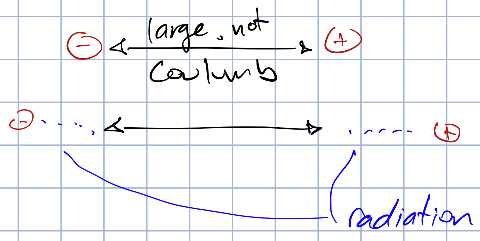
jump between energy levels



no quantum

how many ways of accelerating charges? many -

Brem-Straulen



. . . . ?

low energy

Compton Scattering

Inverse Compton

$\vec{B}$ w/charged particles Lorentz Force

cyclotron & synchotron

look @ E&M spectrum - vague understanding

Temp / Frequency / Wavelength

Maxwells eq^{n}'s like solving for sound description of person playing guitar → just listen!

we'll look at avg's

only want few, impt. information. Maxwell is way too much info.

Macroscopic Description

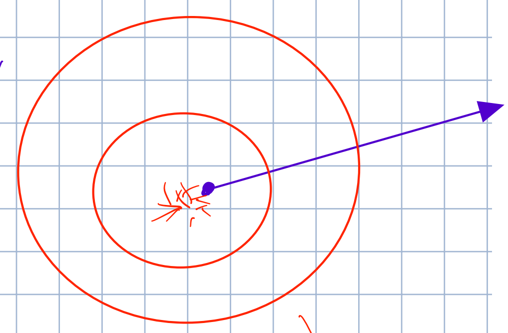
system size $L \gg \lambda$ → don't care about phase

λ ↳ wavelength — don't need microscope to view elephant

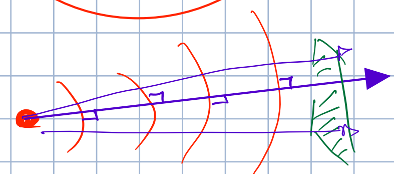
idea of a ray – path of photons

lines everywhere tangent to propogation of EM energy

$\perp$ to surfaces of constant phase



interesting Q: energy carried by field)))



flux : # of rays per area per time

$[\ ]$ $\dfrac{\text{Watts}}{m^2}$

$dE = F\, dA\, dt$

inverse square law

isotropic radiation : constant energy ↔ $F \propto r^{-2}$

isotropic – same in all ∡

homogeneous – " " location

stationary – " " time

what if : not isotropic? ☹

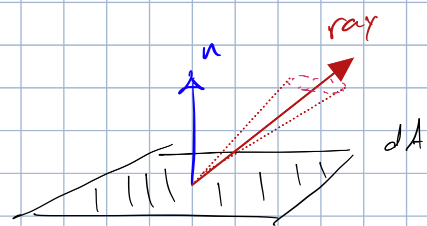
want some directional information

refine idea : look @ energy along neighborhood

brightness/specific intensity.

$dE = I_\nu\, dA\, dt\, d\nu\, d\Omega$

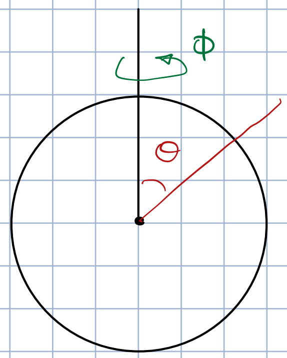
area, time, energy/frequency, angle



Integrating Solid Angle

dimensionless quantity

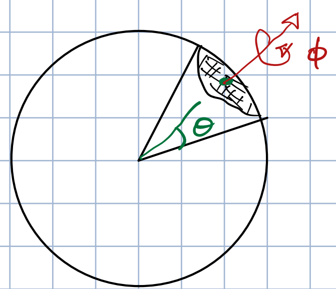
area on unit sphere



$$d\Omega = d\phi \sin\theta \, d\theta$$
$$= -d\phi \, d\mu$$

$\mu = \cos\theta$

$\mu = \sin\theta$



$$\Omega = \int_0^{2\pi} d\phi \int_0^{\theta} \sin\theta \, d\theta$$
$$= -2\pi \int_1^{\cos\theta} d\mu$$

?

review integration dumbass

$$= 2\pi(1 - \cos\theta)$$

if $\theta \ll 1$, can expand $\cos\theta$ s.t. $\Omega = \pi\theta^2 + O(\theta^4)$

Consider flux from solid angle $d\Omega$ incident on oriented area dA

$$dF_\nu = I_\nu \cos\theta \, d\Omega$$

effective area is area normal

direction of ray

1^{st} order

net flux $F_\nu = \int I_\nu \cos\theta \, d\Omega$

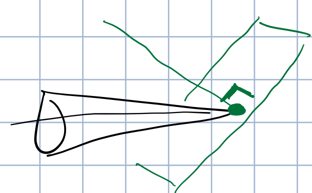
What about flux of momentum thru dA?

momentum!

p_ν

direction of area

2^{nd} order



$E = pc \rightarrow E/c = p$

Future Diego: $E/c \rightarrow dF_\nu/c$

$$p_\nu = \frac{1}{c} \int I_\nu \cos^2\theta \, d\Omega$$

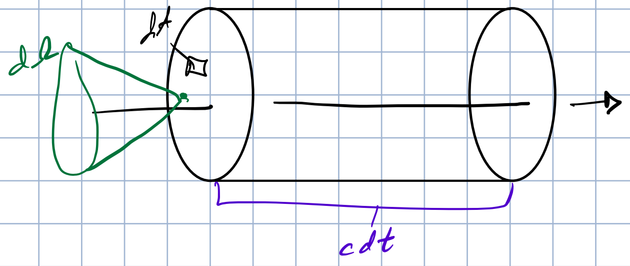
specific - @ specific freq

What about specific energy / unit volume

first: specific energy per Ω

prop. fx $d\Omega$ — solid angle — volume

$$dE = u_\nu(\Omega)\ d\Omega\ dV$$



$$dE = u_\nu(\Omega)\ dA\ \underbrace{cdt}\ d\Omega\ d\nu$$

frequency

but all radiation would've moved out

figure

$$dE = I_\nu\ dA\ d\Omega\ dt\, d\nu$$

def^n of dE ☆

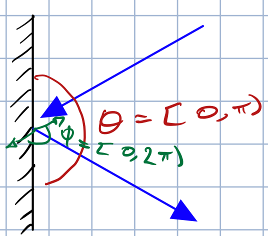
$$u_\nu(\Omega) = I_\nu / c$$

integrate over all solid angles

$$u_\nu = \int u_\nu(\Omega) d\Omega = \frac{1}{c}\int I_\nu\, d\Omega$$

or $u_\nu = \frac{4\pi}{c} J_\nu$ where $\underbrace{J_\nu = \frac{1}{4\pi}\int I_\nu d\Omega}_{J_\nu \text{ mean density}}$

What about pressure?



$$P_\nu = \frac{2}{c}\int I_\nu \cos^2\theta\, d\Omega$$

pressure @ $f = \nu$

$$I_\nu = F_\nu\ \delta(\Omega - \Omega sc)$$

$$\int F_\nu\ \delta(\Omega - \Omega sc) \cos^2\theta\ d\Omega$$

$$F_\nu \int \underbrace{\cos^2\theta}_{\theta\approx 0}\ \underbrace{\delta(\Omega - \Omega sc)\, d\Omega}$$

$$F_\nu \cdot 1 \cdot 1$$

$$F_\nu$$

note for isotropic radiation: $J_\nu = I_\nu$

$$P = \frac{2}{c}\int d\nu\ J_\nu \int \cos^2\theta\, d\Omega = \frac{1}{3} u$$

pressure is 1/3 of energy density