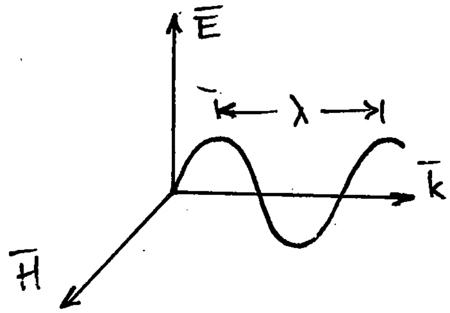
2.58 2/7/06

MODES: CONDUCTION $\vec{q}'' = -k\bar{\nabla}T$ } DIFFUSION BASED PROCESSES

CONVECTION N-S EQNS

RADIATION
- DOES NOT DEPEND ON LOCAL TEMP. GRADIENT
- BALLISTIC
- WAVELENGTH DEPENDENT

THERMAL RADIATION IS BASED ON E.M. WAVES (MAXWELL'S EQNS)



$\bar{E} \times \bar{H} = \bar{k}$

WAVELENGTH: λ

PERIOD: τ

FREQ. $f = \frac{1}{\tau} = \nu$

ANG. FREQ. $\omega = 2\pi f = \frac{2\pi}{\tau}$

WAVENUMBER: $\eta = \frac{1}{\lambda}$

MAGNITUDE OF WAVEVECTOR

$$k = |\bar{k}| = \frac{2\pi}{\lambda}$$

$$c_o = 3\times10^8 \text{ m/s} = \nu\lambda$$

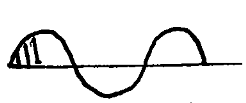
$\omega = c_o k$ "DISPERSION RELATION"

RADIO FREQ.

$\nu \sim 1\text{MHz} \Rightarrow \lambda = 300\text{m}$

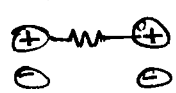
SOLVING MAX. EQN'S

$\Rightarrow$ DON'T REQUIRE PHASE INFORMATION



THERMAL RAD.

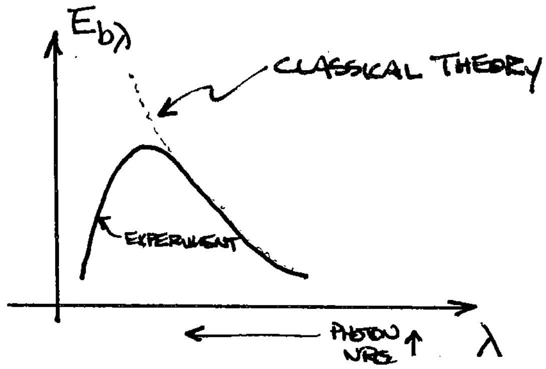
$\lambda \sim 1\mu m \Rightarrow \nu \approx 3\times10^{14}$ Hz (MUCH HIGHER THAN RADIO)

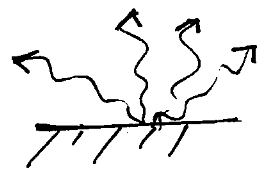


ACCEL./DECEL. CHARGE MOTION CAUSES RADIATION

2/7/06

BLACKBODY RADIATION





$$E_{b\lambda} = \frac{P_\lambda}{dA\, d\lambda} \quad ; \quad E_{b\nu} = \frac{P_\nu}{dA\, d\nu} \Rightarrow \nu = c/\lambda \Rightarrow \nu \sim \frac{1}{\lambda}$$

$$E_{b\nu} = \frac{2\pi h \nu^3 n^2}{c_o^2 \left(e^{\frac{h\nu}{k_B T}} - 1\right)} \left[\frac{W}{m\ Hz}\right] \quad ; \quad k_B = 1.38 \times 10^{-23}\ J/K$$

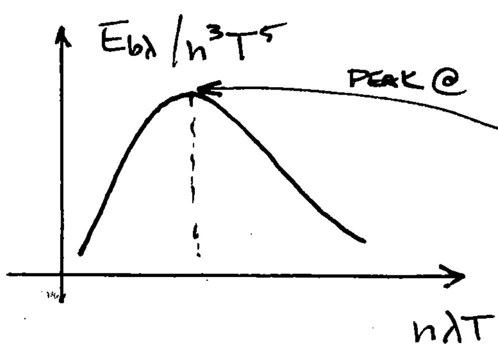
$$h = 6.6 \times 10^{-34}\ J\text{-}s$$

$$n = c_o/c$$

⇓

$$E_{b\lambda} = E_{b\nu}\left(\frac{d\nu}{d\lambda}\right) = \frac{2\pi h c_o^2}{n^2 \lambda^5 \left(e^{h c_o / n\lambda T k_B} - 1\right)}$$

$$\frac{E_{b\lambda}}{n^3 T^5} = \frac{C_1}{(n\lambda T)^5 \left[\exp\left(\frac{C_2}{n\lambda T}\right) - 1\right]}$$



$n\lambda T = 2898\ \mu m K$

$n = 1$ in vac.

$\lambda T \approx 3000\ \mu m K$

$\Rightarrow \lambda \sim 10 \mu m$ EARTH RADIATION (300K)

WHAT IS AREA UNDER BLK. BODY CURVE?

$$E_b(T) = \int_0^\infty E_{b\lambda}\, d\lambda = \int_0^\infty \underbrace{\frac{E_{b\lambda}}{n^3 T^5}}_{f(n\lambda T)} \cdot n^3 T^5 \frac{1}{nT}\, d(n\lambda T)$$

$$d\lambda = \frac{1}{nT} d(n\lambda T)$$

$$\boxed{E_b(T) = n^2 \sigma T^4}$$

("STEPHAN–BOLTZMAN LAW", $\sigma = 5.67 \times 10^{-8} \frac{W}{m^2 K^4}$

CONDITIONS:

① THERMAL EQUILIBRIUM

② OBJECT CURVATURE >> λ

PLANCK SAID: • $E = h\nu \times$ integer

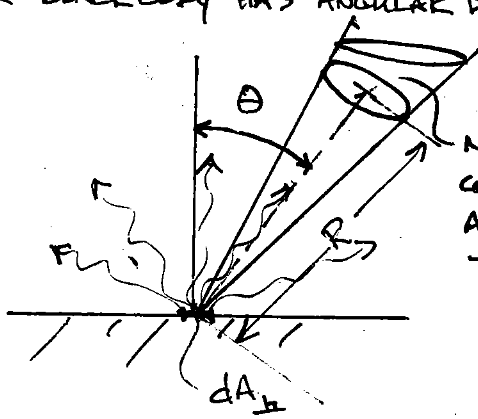
EINSTEIN SAID: • PHOTONS SHOULD HAVE MOMENTUM

(?? de Broglie

$$p = \frac{h}{\lambda}$$

• STIMULATED EMISSION IS POSSIBLE

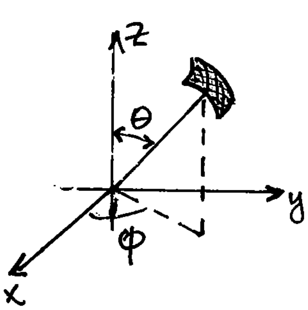
OUR BLACKBODY HAS ANGULAR DEPENDANCE, W.R.T. ITS EMISSION



INTENSITY $I_\lambda = \frac{P_\lambda}{dA_\perp\, d\lambda\, d\Omega}$ ← SOLID ANGLE

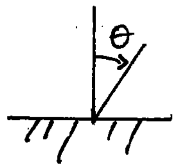
$$= \frac{P_\lambda}{\cos\theta\, dA\, d\lambda\, d\Omega}$$

$$I_{b\lambda} = \text{CONST}$$



$$d\Omega = \frac{dA_\perp}{R^2} = \frac{\sin\theta\, R\, d\phi \cdot R\, d\theta}{R^2} = \sin\theta\, d\theta\, d\phi$$

RECALL POLAR COORDS.



$$\tfrac{1}{2}\text{ SPHERE } \Delta = \int_0^{\pi/2} d\theta \int_0^{2\pi} \sin\phi \, d\phi = 2\pi$$

$$\text{WHOLE SPHERE } O = 4\pi$$

↑ "A SPHERE ICON"

$$E_{b\lambda} = \int_A I_{b\lambda} \cos\theta \, d\Omega = \pi I_{b\lambda}$$

H.W. #1 1.8, 11,
3.4, 4.16
5.13, 18