Highlights from ECE 235: Solid-state Physics

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1 EM wave

1.1 waves

- Traverse wave: oscillation $\perp$ propagation
- Longitudinal wave: oscillation $\parallel$ propagation
- $v = \lambda f$

1.2 EM wave function

$$\begin{cases} E_x = E_0 \sin(kz - \omega t) \\ B_y = B_0 \sin(kz - \omega t) \end{cases} \quad [1$$

where $k = \frac{2\pi}{\lambda}$ (wave number) , $\omega = 2\pi f = kc$ (dispersion relationship), B_0 : magnetic field amplitude, E_0 : electric field amplitude

1.3 EM Energy flux

Energy flux the energy transferred per unit area per unit time in the direction of wave propagation of an EM wave is defined by the Poynting vecter

$$\vec{S} \equiv \frac{\vec{E} \times \vec{B}}{\mu_0}. \quad [2$$

Where $\mu_0 = 1.25663706126e\text{-}6(N \cdot A^{-2})$ is the vacuum permeability.

- Intensity of EM wave is the magnitude of the Poynting vector:

$$I = \langle S \rangle = \frac{E_0^2}{377\Omega} \quad [3$$

where Ω is ohm. Very unorthodoxy I know, but hey we are in Engineering Hall.

- Specially, when EM wave is emitted from a point light source with power P ,

$$I = \frac{P}{4\pi r^2} = \frac{E_0^2}{377\Omega} \quad [4$$

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2 Photoelectric effect

- Energy of a photon

$$E_p = hf = \frac{hc}{\lambda} = \Phi + E_k \quad [5$$

where Φ is the work function of the material, E_k is the kinetic energy of the emitted electron at the surface of the material. $h = 6.26e\text{-}34$ is the Planck constant.

- Motion for Photoelectric effect:

$$E_{k,m} + (\text{-}e)V_m = E_{k,d} + (\text{-}e)V_d \quad [6$$

- stopping potential

$$eV_{\text{stop}} = \frac{hc}{\lambda} - \Phi \quad [7$$

the minimum potential required to stop the emitted electron.

- Threshold frequency& wavelength: set $E_k = 0$:

$$f_t = \frac{\Phi}{h}, \quad \lambda_t = \frac{hc}{\Phi} \qquad [8$$

3 Blackbody radiation

- Stefan-Boltzmann law:

  $$R = \sigma T^4. \qquad [9$$

  Where R is the power radiated per unit area, or energy density. T is temprature in Kelvin, $\sigma = 5.67e\text{-}8(W \cdot m^{-2} \cdot K^{-4})$ is the Stefan-Boltzmann constant.

- Wien's displacement law:

  $$\lambda_{\text{max}} T = b \qquad [10$$

  where $b = 2.89e\text{-}3(m \cdot K)$ is the Wien's constant, and λ_{max} is the wavelength at which the blackbody radiation is maximum, and T is the temprature in Kelvin of the blackbody.

- Rayleigh-Jeans law:

  $$\begin{aligned} R(\lambda) &= \frac{1}{4} c u(\lambda), \\ u(\lambda) &= 8\pi k T \lambda^{-4} \end{aligned} \qquad [11$$

  WHere R is radiation power per unit area, or energy density, u is the energy density of radiation, c is the speed of light, and $k = 8.617e\text{-}5\ \text{eV/K} = 1.38e\text{-}23 J \cdot K^{-}1$ is the Boltzmann constatn This law is valid for long wavelength, but it diverges at short wavelength.

- Planck's law:

  $$u(\lambda) = \frac{8\pi h c \lambda^{-5}}{e^{hc/\lambda k T} - 1} \qquad [12$$

  where $k = 1.38e\text{-}23(J \cdot K^{-1})$ is the Boltzmann constant, h is the Planck constant, T is the temprature in Kelvin of the blackbody.