11.1 a)

Given $\psi(x) = Ae^{ikx} + Be^{-ikx}$

(11.15)

and that $\psi(x) = e^{ikx} u_k(x)$

(11.23)

and $u_k(x) = A e^{i(q-k)x} + B e^{-i(q+k)x}$, $q = \sqrt{2mE}$

$$\underbrace{\left[E + \frac{\hbar^2}{2m}\frac{d^2}{dx^2}\right]\psi(x)}_{} = \sum_{n=-\infty}^{\infty} V_0\, \delta(x - n\Delta)\, \psi(x)$$

Δ: distance between bound electrons

$$\left[\lim_{\varepsilon \to 0}\int_{-\varepsilon}^{\varepsilon} dx = \text{Int}\right] \underline{\underline{\text{def}}}$$

$$\underbrace{\text{Int}\ \underbrace{E\,\psi(x)}_{\substack{=0 \\ (\text{symmetry})}} + \frac{\hbar}{2m}\,\text{Int}\ \underbrace{\frac{d}{dx^2}\psi(x)}_{= \left.\frac{d\psi}{dx}\right|_{-\varepsilon}^{\varepsilon}}}_{} =$$

$$= e^{ikx} \left.\frac{du}{dx}\right|_{-\varepsilon}^{\varepsilon}$$

$$\frac{du}{dx} = Ai(q-k)\, e^{i(q-k)x} + B(-i(q+k))\, e^{-i(q+k)x}$$

$$e^{ikx} \frac{du}{dx} = Ai(q-k)\, e^{iqx} - Bi(q+k)\, e^{-iqx}$$

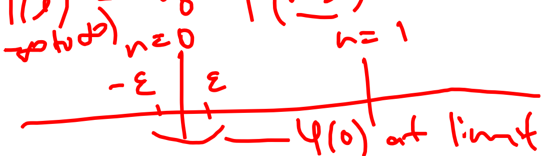
?

$$\int f(x)\, \delta(x - x_0)\, dx = f(x_0)$$

$$\therefore \int V_0\, \delta(x - x + n\Delta)\, \psi(x) = V_0\, \psi(n\Delta) = V_0 (A+B)\ \text{Rm},$$

Only choose one n (not ~~...~~)

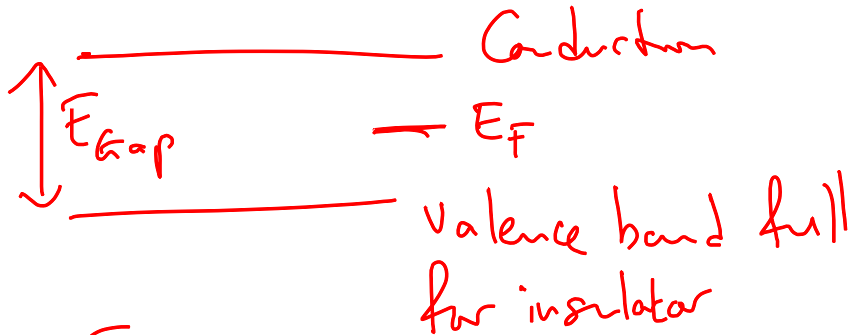
because we



$$\psi = A\cancel{\phi} + B\cancel{\phi}$$

11.2 $f(E) = \frac{1}{1+e^{(E-E_F)/kT}} = \frac{1}{1+\ ?}$

$$= \frac{1}{1+e^{E/2kT}}$$



$$E = \frac{E_{Gap}}{2} + E_F$$

Much lower probability for Diamond (10^{-42}) than Si and Ge.

11.3

$$n = 2\left(\frac{m_n^* kT}{2\pi\hbar^2}\right) e^{-(E_c - E_F)/kT} \qquad \hbar = \frac{h}{2\pi}$$

$$n_i^2 = N_N N_p e^{-E_g/kT} = np$$

product of occupancies.

$$N_N = 2\left(\frac{m_n^* kT}{2\pi\hbar^2}\right)^{3/2} \quad \text{(defined in 11.43)}$$

11.4/

11.5 Voltage V 1.8 V

Capacitance C 1 fF

Resistance R

a) Energy stored in capacitor is $\frac{1}{2}CV^2 = 1.25 \times 10^{-13}$ J

b) $I = \frac{V - V_c}{R} = \frac{dQ}{dt} = \frac{C\,dV}{dt}$

$\Rightarrow \frac{dV_c}{dt} = \frac{1}{RC}(V - V_c) \Rightarrow I = \frac{V}{R} e^{-t/RC}$

$$P = \int_0^\infty I^2 R \, dt = \int_0^\infty \frac{V^2}{R} e^{-2t/RC} dt = \frac{1}{2} CV^2.$$

c) $I = \dfrac{\frac{Vt}{\tau} - V_c}{R}$

$$\frac{dV_c}{dt} = \frac{1}{RC}\left(\frac{V}{\tau}t - V_c\right)$$

d) Charging costs $\frac{CV^2}{2}$, same for discharging.

$\therefore$ energy cost is CV^2

$$\frac{1}{CV^2} = 4\times10^{12}\ Hz$$

e) Power consumed is 10^9 transistors $\times$ CV^2 each

$\times$ 1 GHz

$$= 10^9 \times 2.5\times10^{-13} \times 10^9$$

$$= 2.5\times10^5\ W$$ kilo watts!

f) Capacitance is 1 fF

$$Q = CV = 5\times10^{-14}\ C$$

$$\text{no. electrons} = \frac{5\times10^{-14}}{1.6\times10^{-19}} = 3\times10^5 \text{ electrons.}$$