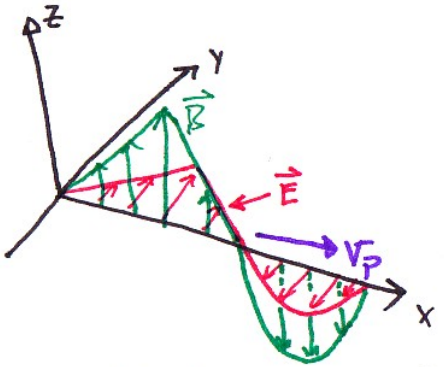
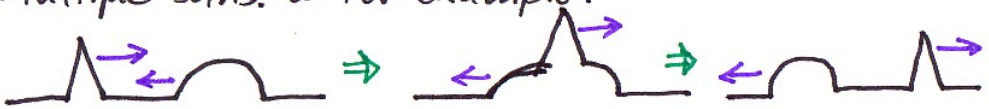
Plane waves + MEQ + vacuum

$E = cB$



The superposition principle for traveling waves

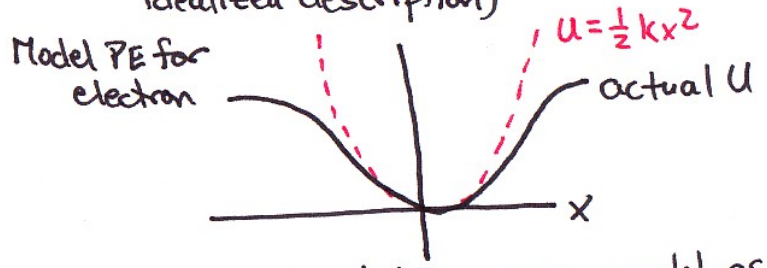
The wave eqn is a linear DEQ ⇒ can superpose multiple solns. For example:



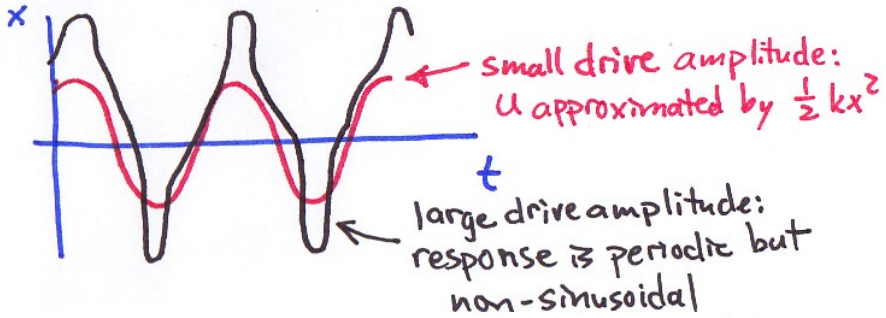
Non-linear waves

For waves traveling in a medium, at very high amplitudes the DEQs become nonlinear ⇒ no longer get simple superposition

example: frequency-doubling crystal (highly idealized description)



Excite with sinusoidal em wave, model as harmonic oscillator

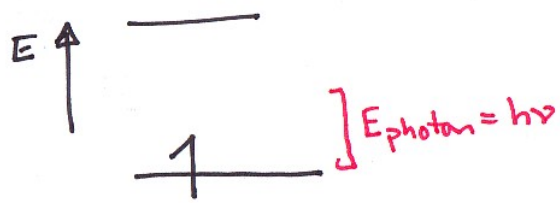


Can Fourier synthesize the non-sinusoidal response by summing responses at $\omega, 2\omega, 3\omega, \ldots$

⇒ electron radiates at $\omega, 2\omega, 3\omega, \ldots$

⇒ Get some photons out at 2ω!

Another example of non-linear waves: two-photon absorption



Irradiate molecule with photons of half the required energy. If intensity is extremely high, can essentially absorb two photons at once & cause the electron to jump to the higher level.

Can localize where the intensity is high enough by the intersection of two laser beams or by the "focussing" effect of a sharp metal tip.

The Poynting vector

$$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$$

points in the direction of propagation

Section 9.10 → $|\vec{S}|$ = intensity

Traveling sinusoidal waves

$$y = A \sin[k(x - v_p t)] = A \sin(kx - \omega t)$$

conventional way to write

phase velocity $v_p = \frac{\omega}{k}$