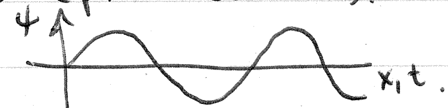
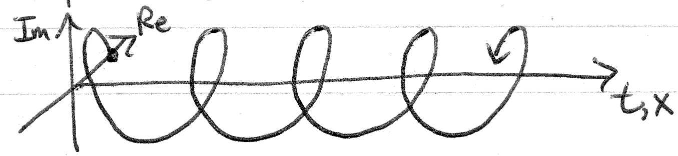
$\Psi(\vec{x},t) = N e^{i(\vec{k}\cdot\vec{x} - \omega t)}$ vs. $\vec{x}(t)$ classical particle

$\Rightarrow$ today: $= N e^{i(\vec{p}\cdot\vec{x} - Et)/\hbar}$ next $\vec{F} = m\vec{a} \Rightarrow$ T.D.S.E.

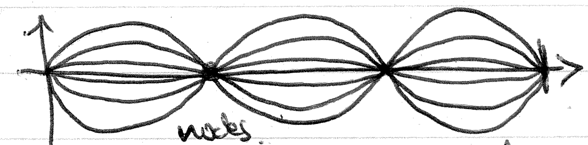
* complex #'s.
* wave number $\boxed{\begin{array}{l} E = \hbar\omega \\ p = \hbar k \end{array}}$ back to L later!
* pure momentum waves (plane waves).
  - linear polarized.



  - circular polarized

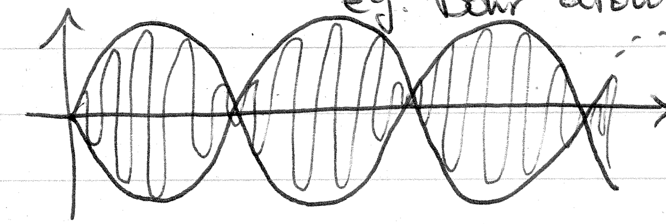


  - standing waves.
    λ? f? v?
    (skipping rope waves)



modes.
eg. Bohr atom

  - beating waves.
    - carrier frequency.
    - packet frequency.
    - AM radio?

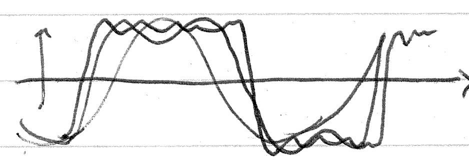


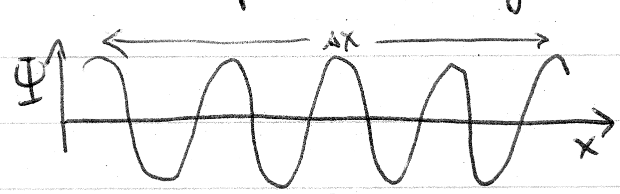
prev demos: rope: circular, standing; tuning forks.

* dispersion - frequency dependent velocity.

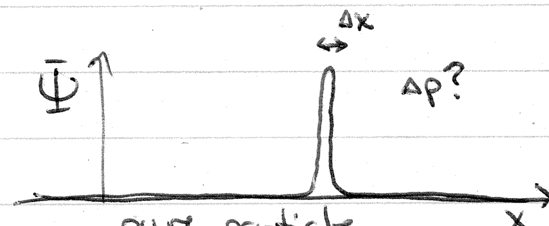
$\Rightarrow$ next class: general wave packets.

* Fourier series. -synthesizers
* Heisenberg uncertainty. $\Delta p \cdot \Delta x \geq \frac{\hbar}{2}$, $\Delta E\, \Delta t \geq \hbar/2$
* wave - particle duality.





pure wave



pure particle

6

* linear polarized wave.

* wave number : $\Psi(x,t) = A\cos\left(\underbrace{\frac{2\pi x}{\lambda}}_{\vec{k}\cdot\vec{x}} - \underbrace{\frac{2\pi t}{T}}_{\omega t}\right)$ (2π when $x=\lambda$; $\nu = +$; 2π when $t = T$)

$E = hf = \frac{h}{2\pi} 2\pi f = \hbar\omega$

f = cycles/time $\qquad \omega$ = radians/time $= 2\pi f = \frac{2\pi}{T}$

likewise

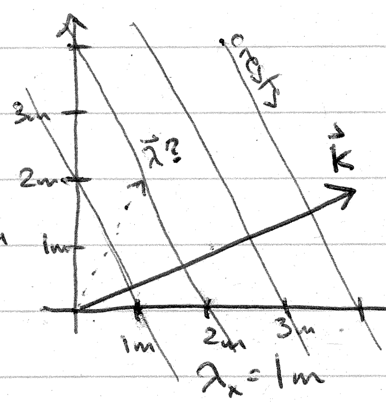
	$\hbar$	
E	ω	time
p	k	space
particle	wave	

let $k = \frac{\text{radians}}{\text{dist}} = \frac{2\pi}{\lambda}$ $\qquad p = \frac{h}{\lambda} = \frac{h}{2\pi}\cdot\frac{2\pi}{\lambda} = \hbar k$

"spatial angular frequency"

why is it better? $\Psi(\vec{x},t) = A\cos(\vec{k}\cdot\vec{x} - \omega t)$

travels in direction $\vec{k}$



velocity? depends on which way.

$k_x = \frac{2\pi}{1m}$

$k_y = \frac{2\pi}{2m}$

$v = \frac{\omega}{k}$

phase velocity. for pure waves.

$v_n = \frac{\omega}{\vec{k}\cdot\hat{n}}$

* complex #'s - see handout.

* circular wave - easy with complex #'s

let $\hat{x} \leftrightarrow 1 \quad \hat{y} \leftrightarrow i$

How to get frequency? $-i\frac{\partial}{\partial x}$ or $i\frac{\partial}{\partial t}$

$\Psi(\vec{x},t) = N e^{i(\vec{k}\cdot\vec{x} - \omega t - \overset{\text{phase}}{\phi})}$

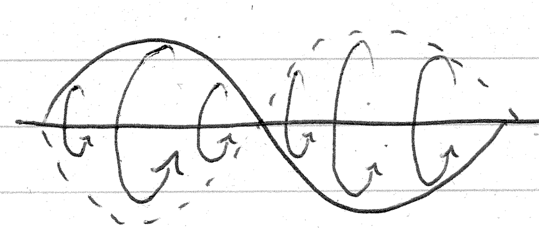
$= \underbrace{(N e^{-i\phi})\, e^{i\vec{k}\cdot\vec{x}}}_{\substack{\text{complex amplitude} \\ \psi(x)}} \underbrace{e^{-i\omega t}}_{\text{time dependence}}$

* standing wave:

$\Psi_1 + \Psi_2 = Ae^{i(kx-\omega t)} + Be^{i(-kx-\omega t)}$

if $A=B$: $= A(e^{ikx} + e^{-ikx})e^{-i\omega t}$

$= 2A\cos(kx)\, e^{-i\omega t}$



"skipping rope wave"

* beats: - see handout.