Phys 231 2026

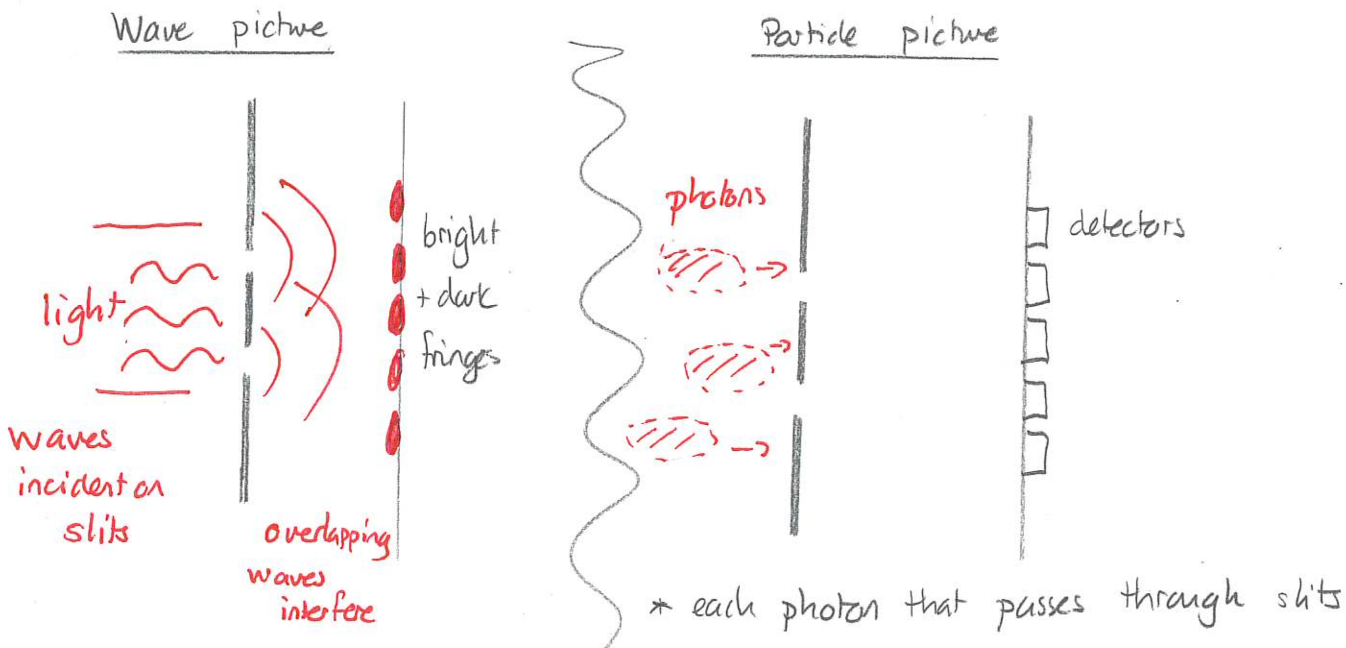
Lecture 5

Mon: HW by 5pm

Read 3.1 → 3.3

Interference of light

The particle picture of light describes certain matter-light interactions well - classical physics fails to do this. How would it describe interference phenomena? One example is double slit interference, where light passes through two slits toward a detector / barrier. The observed phenomena are describe well by classical physics



* each photon that passes through slits arrives at one detector
* even though photons are prepared identically, their arrival locations will vary statistically.

DEMO: PhET Wave Interference

1. High intensity - observe fringes vert ~ 75% sep ~ 50%

2. Single photons - observe statistics

DEMO: Lyman page.

We cannot predict the precise arrival location of any single photon, even if we know the arrival location of preceeding photons. We can hope to

Predict the probability of arrival at any location

Quantum theory will provide a method to do this.

DEMO: Photon Interference Double Slits Slide

The arrival probability curve is similar to the intensity profile curve. This suggests how we could use quantum theory to predict the probability of arrival

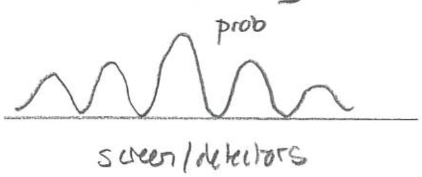
Situation: light incident on barriers and slits

Physical

Light consists of photons

Photons pass through barrier + slits and later arrive at detectors

Observe probability of arrival



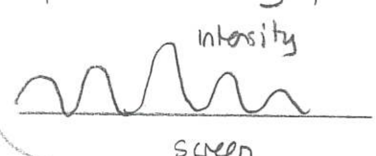
photon

energy

Mathematical

Associate a wave with light. Requires frequency wavelength

Use wave physics (interference, etc, ..) to predict intensity profile



Intensity profile predicts probability distribution

We will see that this framework will describe light as a particle and also matter (e.g. electrons, neutrons,...)

Thus we need to develop a mathematical language to describe waves.

Traveling waves in one dimension → 6.1.2

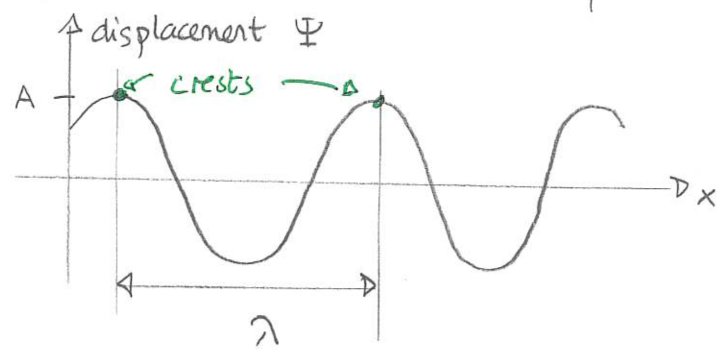
We start by considering waves that travel along a single straight direction

DEMO: PhET W.o.a.S.

- no end
- oscillate → traveling wave

The animation shows a sinusoidal traveling wave. This is a wave such that, at any single instant, the profile is sinusoidal. Consider a snapshot

This wave can be described via:



1) amplitude, A, This is the maximum displacement from equilibrium

2) wavelength, λ, is the distance between successive crests (in m)

3) frequency, f. Let T be the time between arrival of successive crests at one location. The frequency is

$$f = 1/T \quad \text{(in Hz)}$$

We would observe that the pattern propagates. The speed with which the pattern propagates is called the wave speed, v, and

$$\boxed{v = \lambda f}$$

Mathematically the wave can be represented by displacement

$$\boxed{\Psi(x,t) = A\cos(kx - \omega t + \phi)}$$

where

1) $k = 2\pi/\lambda$ is the wavenumber

2) $\omega = 2\pi f$ is the angular frequency

3) ϕ is the phase shift

For calculation purposes the argument must be in radians. In a HW assignment you will show that the wave expression satisfies:

1) $\Psi(x \pm \lambda, t) = \Psi(x,t)$ $\Rightarrow$ ~~eb~~ jump forward by $+\lambda$ $\Rightarrow$ same wave

2) $\Psi(x, t \pm T) = \Psi(x,t)$ $\Rightarrow$ jta at moment T later $\Rightarrow$ same wave.

Quiz1 70%

Starting with $v = \lambda f$ we can show that

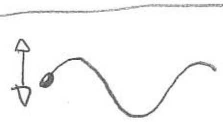
$$\boxed{v = \omega/k \Rightarrow \omega = vk}$$

Quiz2

The phase of the wave refers to a lateral shift in the wave.

DEMO: Wave shift slides

How could we associate these parameters with wave production?



oscillate

the way in which the string is oscillated determines parameters

$\rightarrow$ f determined by rate of oscillation

A " by amplitude of oscillation

ϕ " by position of oscillator at $t=0$

1 Wave equation

The *classical wave equation* appears by applying basic physics in many different situations and describes a displacement $\Psi(x,t)$ via

$$\frac{\partial^2\Psi}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2\Psi}{\partial t^2}.$$

a) Show that

$$\Psi(x,t) = A\cos(kx - \omega t + \phi)$$

satisfies the classical wave equation provided that k, ω and v satisfy a particular relationship.

b) Will

$$\Psi(x,t) = A\cos(kx + \omega t + \phi)$$

satisfy the classical wave equation?

c) Will

$$\Psi(x,t) = A\sin(kx + \omega t + \phi)$$

satisfy the classical wave equation?

Answer: a)

$$\frac{\partial\Psi}{\partial x} = -kA\sin(kx-\omega t+\phi) \qquad \frac{\partial\Psi}{\partial t} = +\omega A\sin(kx-\omega t+\phi)$$

$$\frac{\partial^2\Psi}{\partial x^2} = -k^2A\cos(kx-\omega t+\phi) \qquad \frac{\partial^2\Psi}{\partial t^2} = -\omega^2A\cos(kx-\omega t+\phi)$$

Substitution gives:

$$-k^2\cancel{A\cos(kx-\omega t+\phi)} = \frac{1}{V^2}\left(-\omega^2\cancel{A\cos(kx-\omega t+\phi)}\right)$$

$\Rightarrow k^2 = \omega^2/V^2$ we need $|\omega = kV$ or $k = \omega/V$

b) the derivation will be the same with $\omega \to -\omega$ and will give the same result

c) Yes differentiating sin twice returns $-\sin$ etc..