Physical Optics

37.1-37.4, 38.1-38.3

Light is an *electromagnetic wave.*

Wave properties:

Diffraction – bends around corners, spreads out from narrow slits

Interference – waves from two or more coherent sources interfere

Background reading: 34.7, 35.1

Practice: Chapter 37,

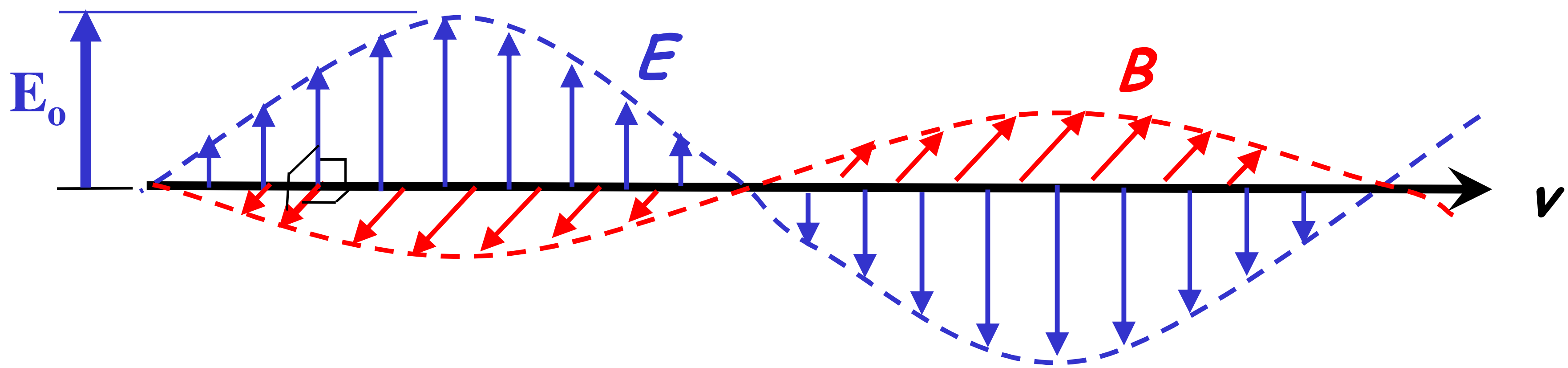
Objective Questions 2, 3, 9

Conceptual Questions 3, 7

Problems 5, 13, 19, 52

Electromagnetic Waves

$\vec{E}, \vec{B}, \vec{v}$ all $\perp$



Usually we keep track of the electric field $\mathbf{E}$:

$$\vec{\mathbf{E}}(x,t) = \vec{\mathbf{E}}_o \sin(kx - \omega t)$$

amplitude

These are transverse waves, with two independent polarization directions.

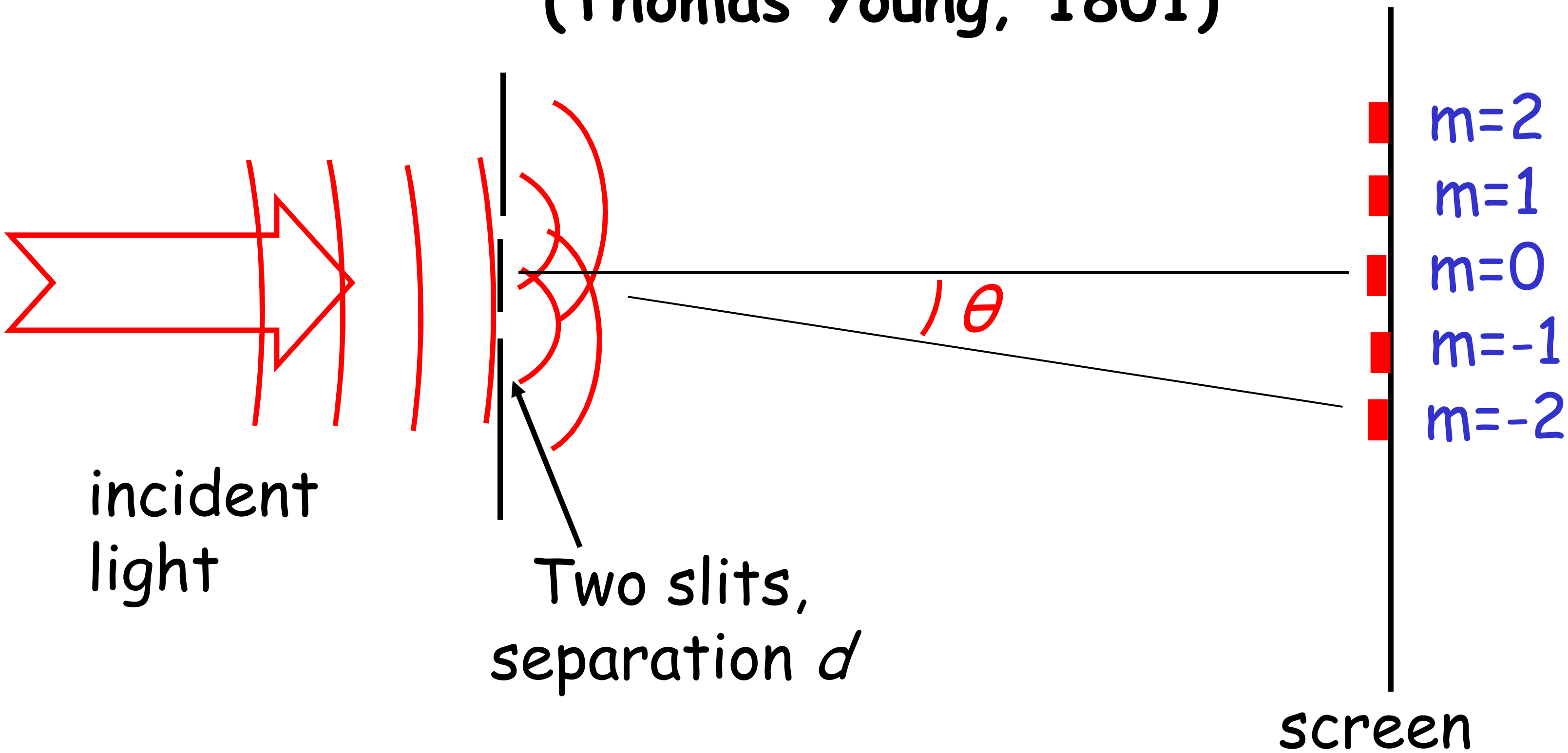
The Electromagnetic Spectrum

λ (m)		f (Hz)
300	Radio	10^6
3	TV	10^8
3×10^{-3}	Microwave	10^{11}
3×10^{-6}	Infrared	10^{14}
7×10^{-7}		5×10^{14}
	Visible	
4×10^{-7}		
3×10^{-9}	Ultraviolet	10^{17}
	X rays	
3×10^{-12}	γ rays	10^{20}

Infrared	
	780 nm
Red	
Yellow	600 nm
Green	550 nm
Blue	450 nm
Violet	
	380 nm
Ultraviolet	

Double Slit

(Thomas Young, 1801)

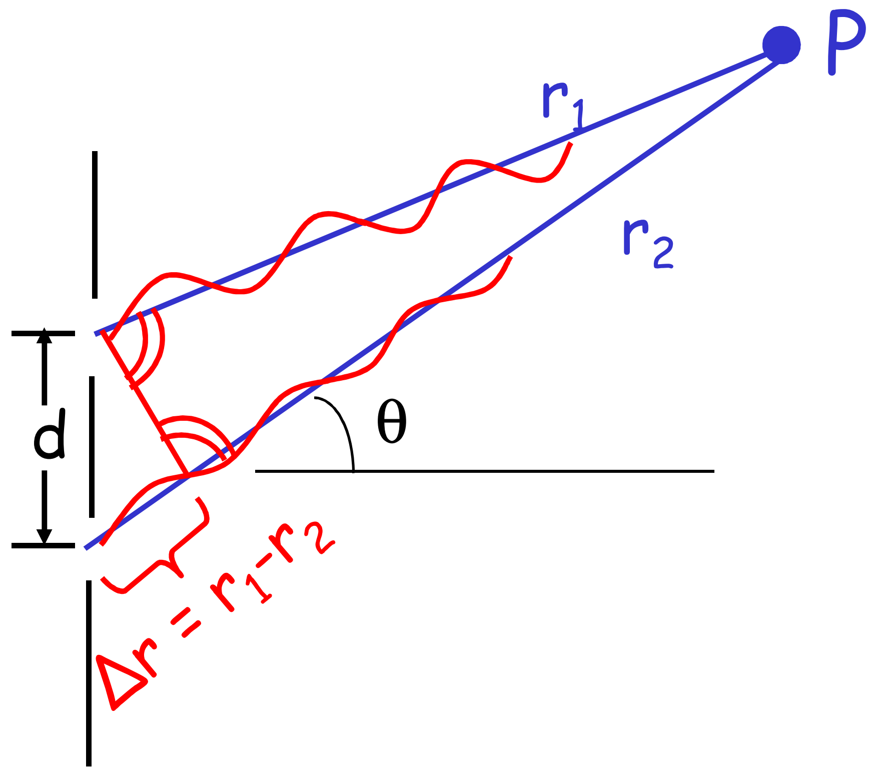


<u>Result</u>: Many bright "fringes" on screen, at angles

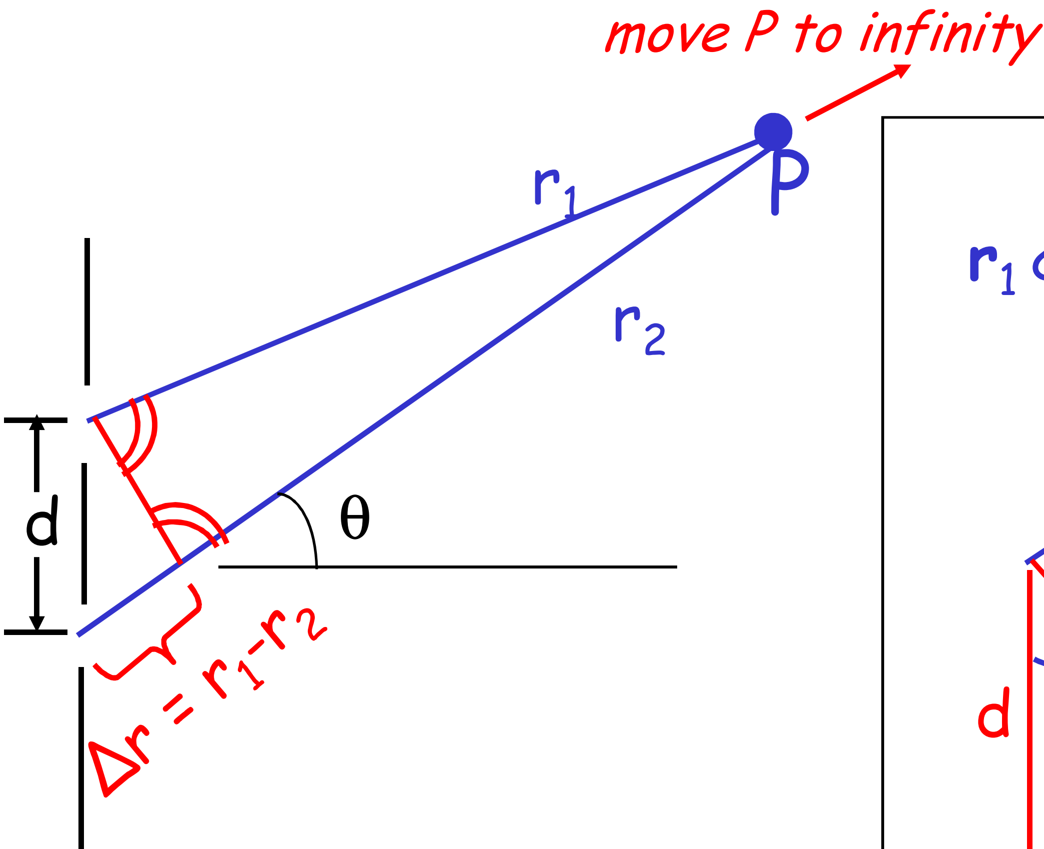
$$\sin\,\theta = m\,{}^{\lambda}\!/_{d}\,, \quad m = 0, \pm 1, \pm 2, \ldots$$

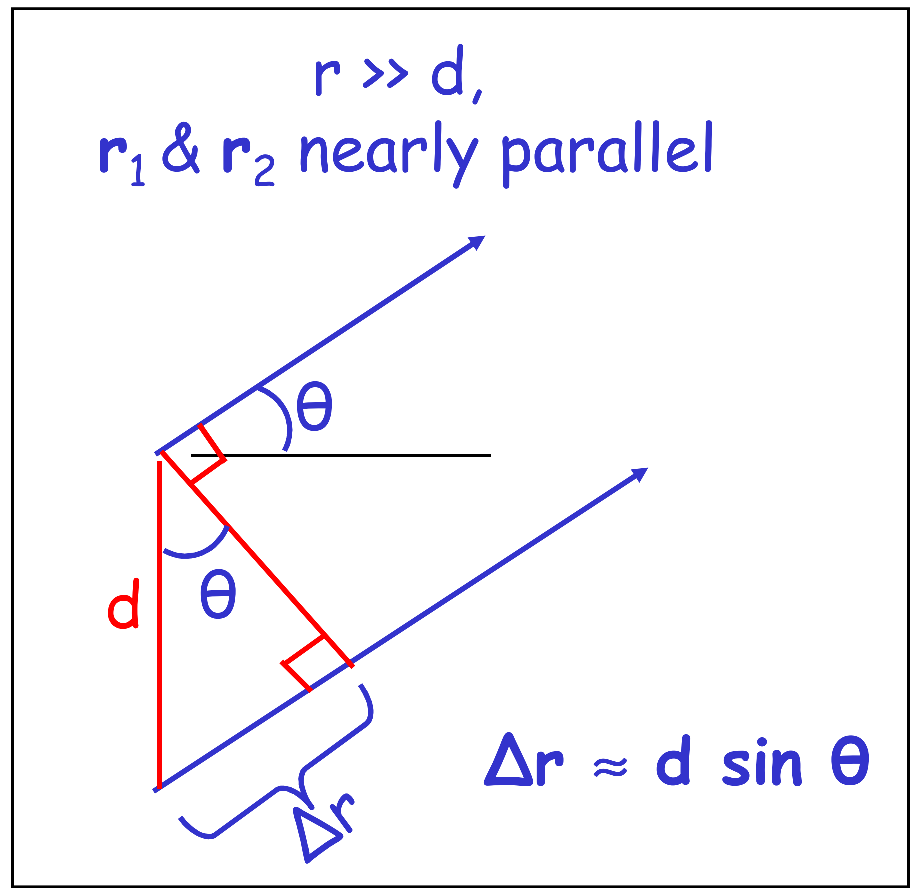
The slits act as sources in phase. Due to diffraction, the light spreads out after it passes through each slit. When the two waves arrive together at some point P on the screen, they are out of phase, due to the difference in the length of the paths. This path difference varies from place to place on the screen.

The bright fringes (interference maxima) are at points for which the path difference Δr is equal to an integer number of wavelengths.



For light, the slits will usually be very close together compared to the distance to the screen. So we will place the screen "at infinity" to simplify the calculation.





Approximate rules for screen very far from slits:

<u>Constructive Interference</u>: (bright)

$\Delta r = m\lambda$,

or

$d \sin\theta = m\lambda, \quad m = 0, \pm 1, \pm 2, \ldots$

<u>Destructive Interference</u>: (no light)

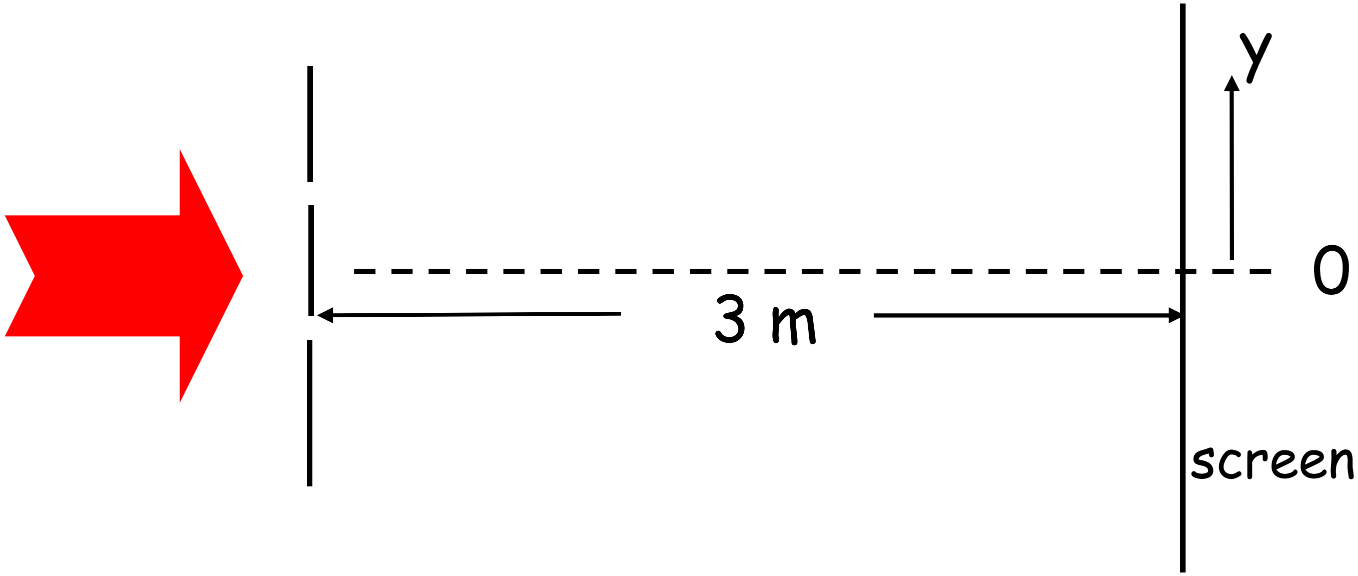
$\Delta r = (m + ½)\lambda$,

or

$d \sin\theta = (m + ½)\,\lambda, \quad m = 0, \pm 1, \pm 2, \ldots$

Example

2 slits, 0.20 mm apart; red light (λ = 667 nm)



Where are a) the bright fringes?
b) the dark lines?

(give values of y)

Quiz

If you decrease the distance between the slits by a factor of 2, but keep the wavelength of light the same, what happens to the pattern on the screen?

A) *The bright "fringes" will be half as far apart*
B) *The bright fringes will be twice as far apart*
C) *The fringes will remain in the same place*

Quiz

If the wavelength and slit separation are both decreased by half, what happens to the pattern?

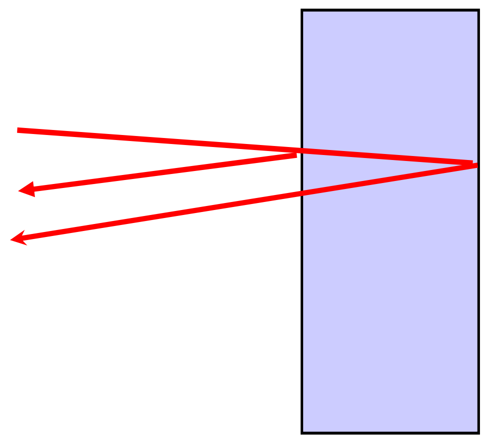
A) The bright "fringes" will be half as far apart
B) The bright fringes will be twice as far apart
C) The fringes will remain in the same place

Coherence

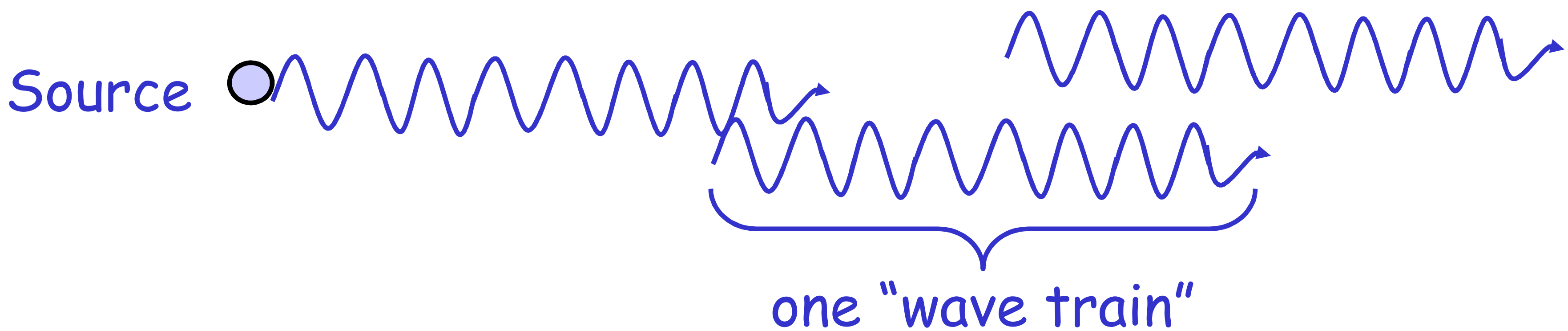
- *To show interference, waves must have a phase difference which remains constant in time; we say the waves must "coherent".*

- *For light beams: Split the light from a single source into two beams, which can then interfere.*

eg. using a thin transparent film:



A limitation is the "coherence length" of the original beam:



L_C = coherence length
= length of one "wave train"

Different wave trains are randomly out of step.

The interference effects disappear if the path difference $> L_C$

Two small light bulbs are placed 1 cm apart. Will you see interference fringes at a distance of 100 m?

A) Yes, if the lights are bright enough.
B) No.
C) Not with light bulbs, but it would work if you used two small laser pointers.