Diffraction occurs when a wave passes thru an opening whose size is $<< \lambda$ QB.1.

[eg water]

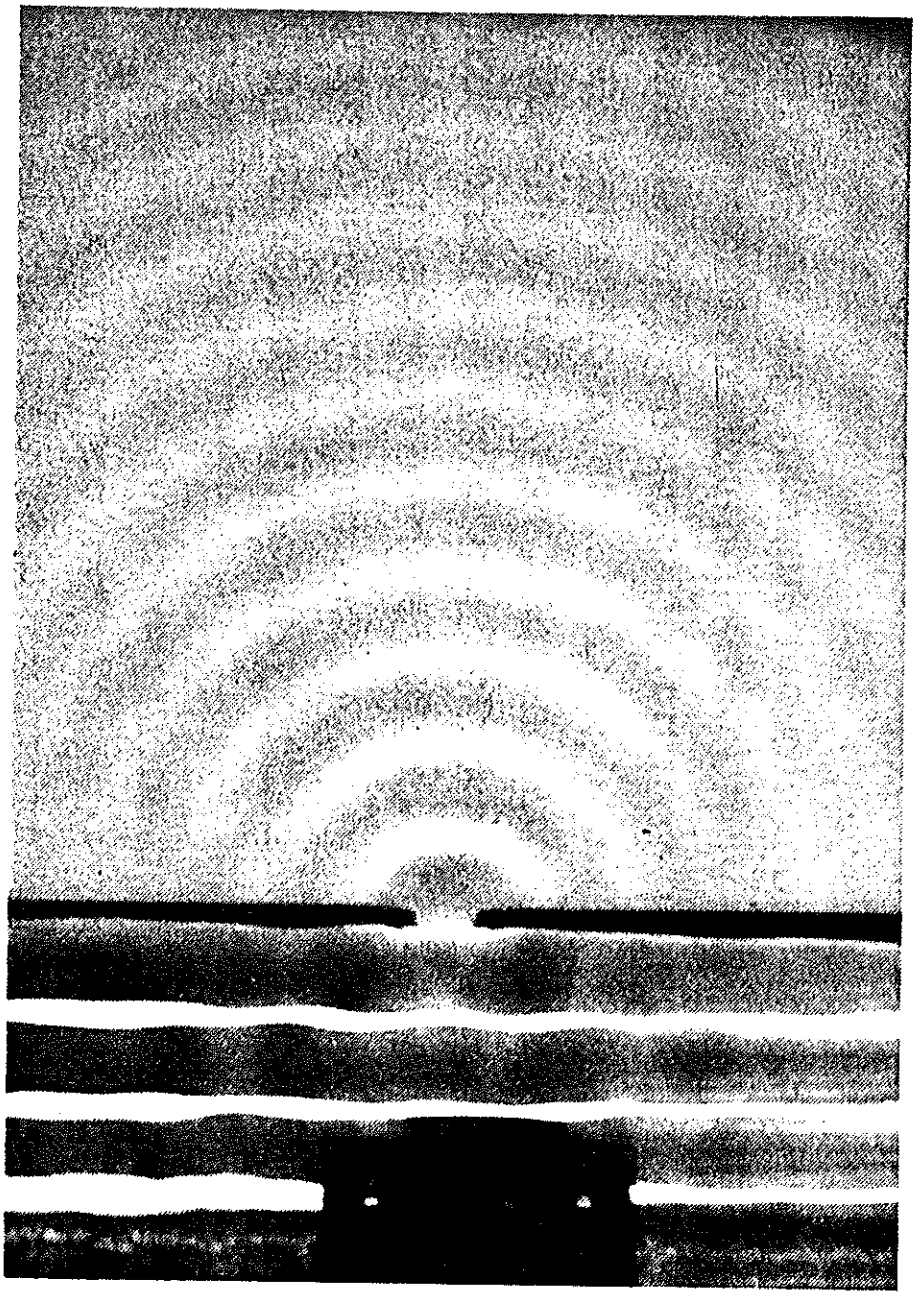
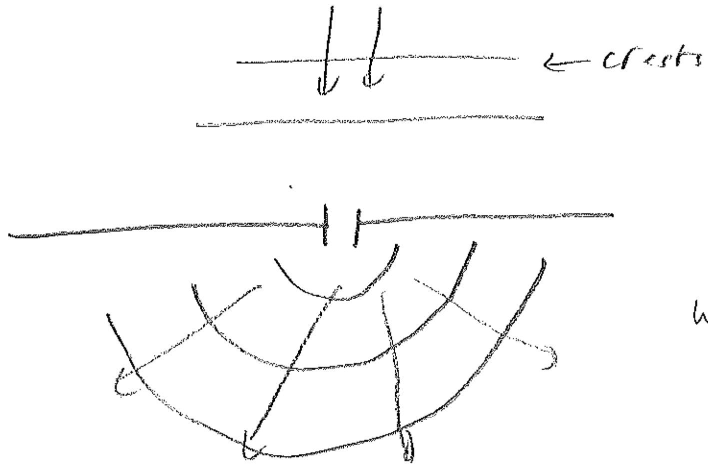


Figure 2 Diffraction of water waves at a slit in a ripple tank. Note that the slit width is about the same size as the wavelength. Compare with Fig. 1*c*.

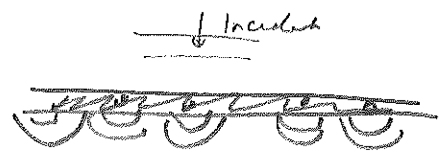
H+R, ch 47, fig 2



When a wave passes thru an aperture whose size $\ll \lambda$, diffraction occurs

[Explain, but do not work, the physical basis for this:

What is an opaque screen? Something that "blocks" all light. How does it do this? By scattering the incident wave to set up a counterbalancing wave.



The sum of incident wave + scattered waves exactly adds up to zero behind the screen: cooperative effort

- Need a certain thickness of material to get complete cancellation — thin films of gold transmit some light

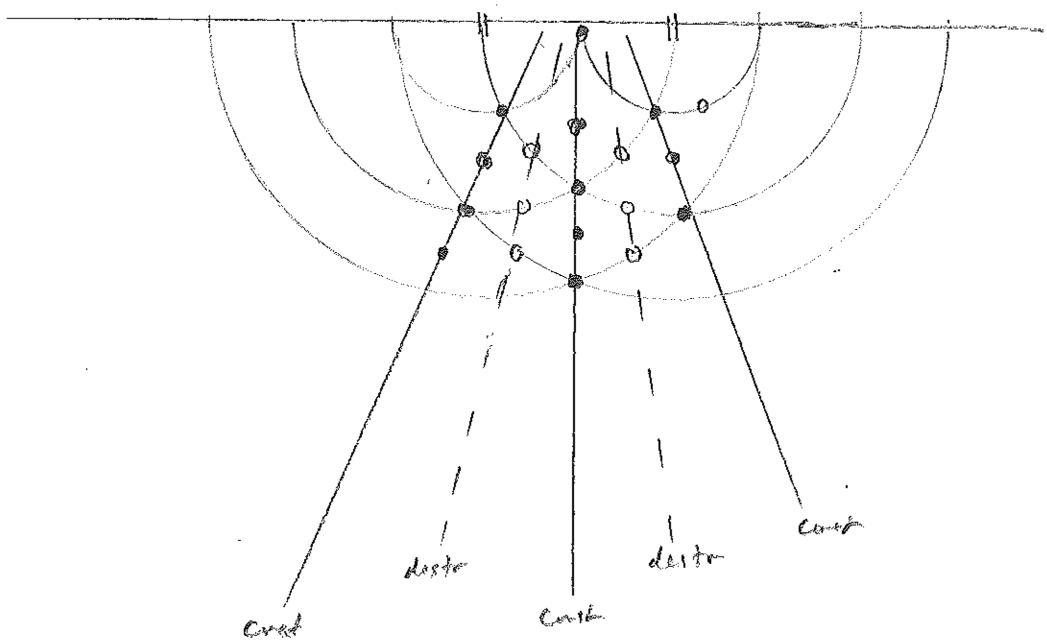
(How does it do it? By responding; as e.g. a floor responds to gravity by setting up an equal normal force)

But if there is a gap in screen, someone's not doing their job... What is the job of the electrons in the gap that have gone AWOL? To scatter:

$E_{net} = \underbrace{E_{tot}}_{=0} - E_{gap}$. So net field is exactly negative of the would-be scattered wave.]

Double slit interference

[What if two portions of screen are missing? Two scattered waves]



perhaps omit this.

It is hard to draw on board & to copy into their notes...

[Draw circles around slits,
put dots where crests & troughs reinforce (const)
Put open circles where crests & troughs cancel]

[show HRK (5e), 41-2]

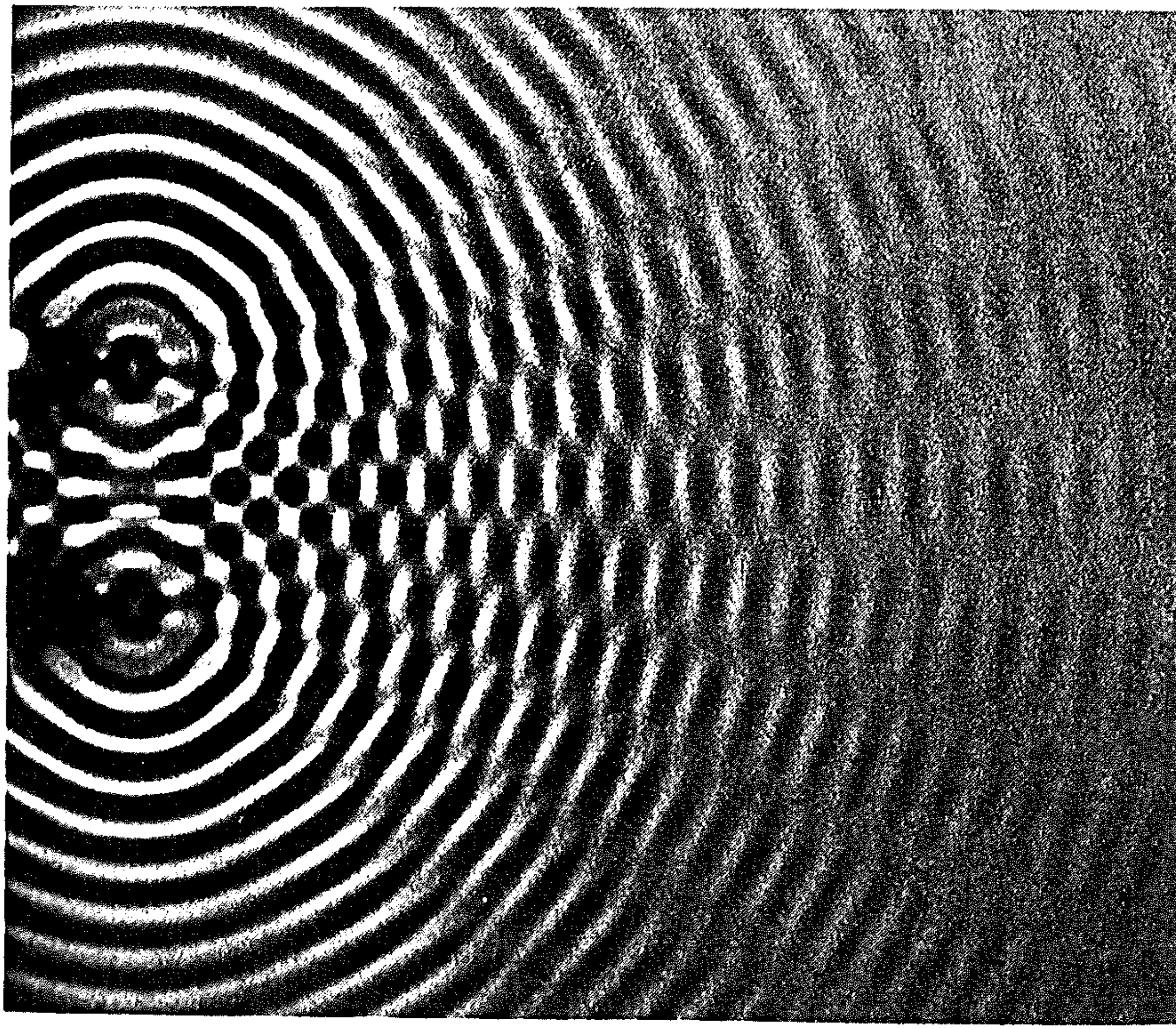
[Place screen to see dark & bright fringes]
[show HRK (5e) 41-4]

[DEMO: laser on wall w/ middle double slit]

OB2.2

HRK(5e) ← 41-4

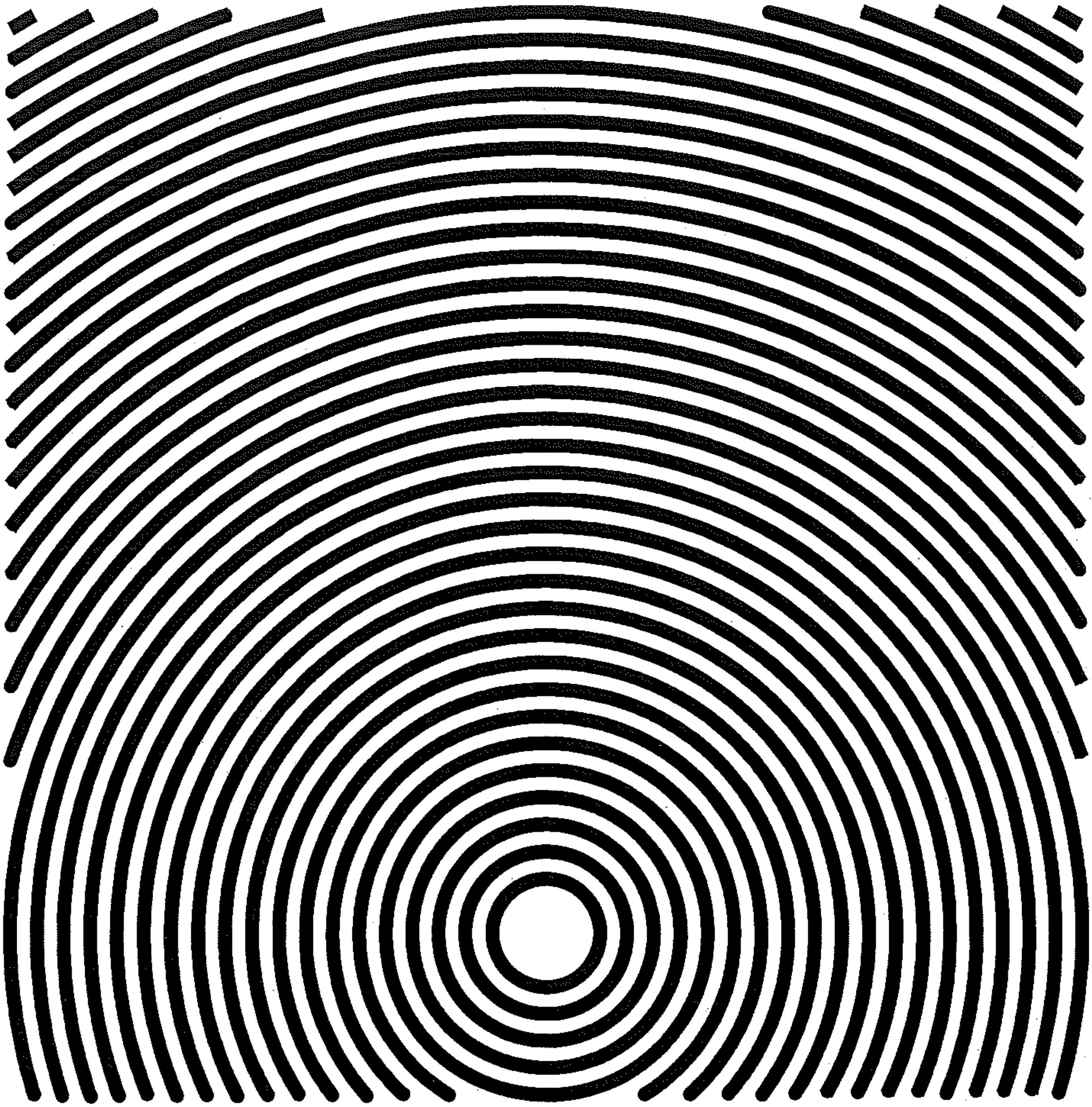
Figure 2 The interference pattern, consisting of bright and dark bands or fringes, that would appear on the screen of Fig. 1.

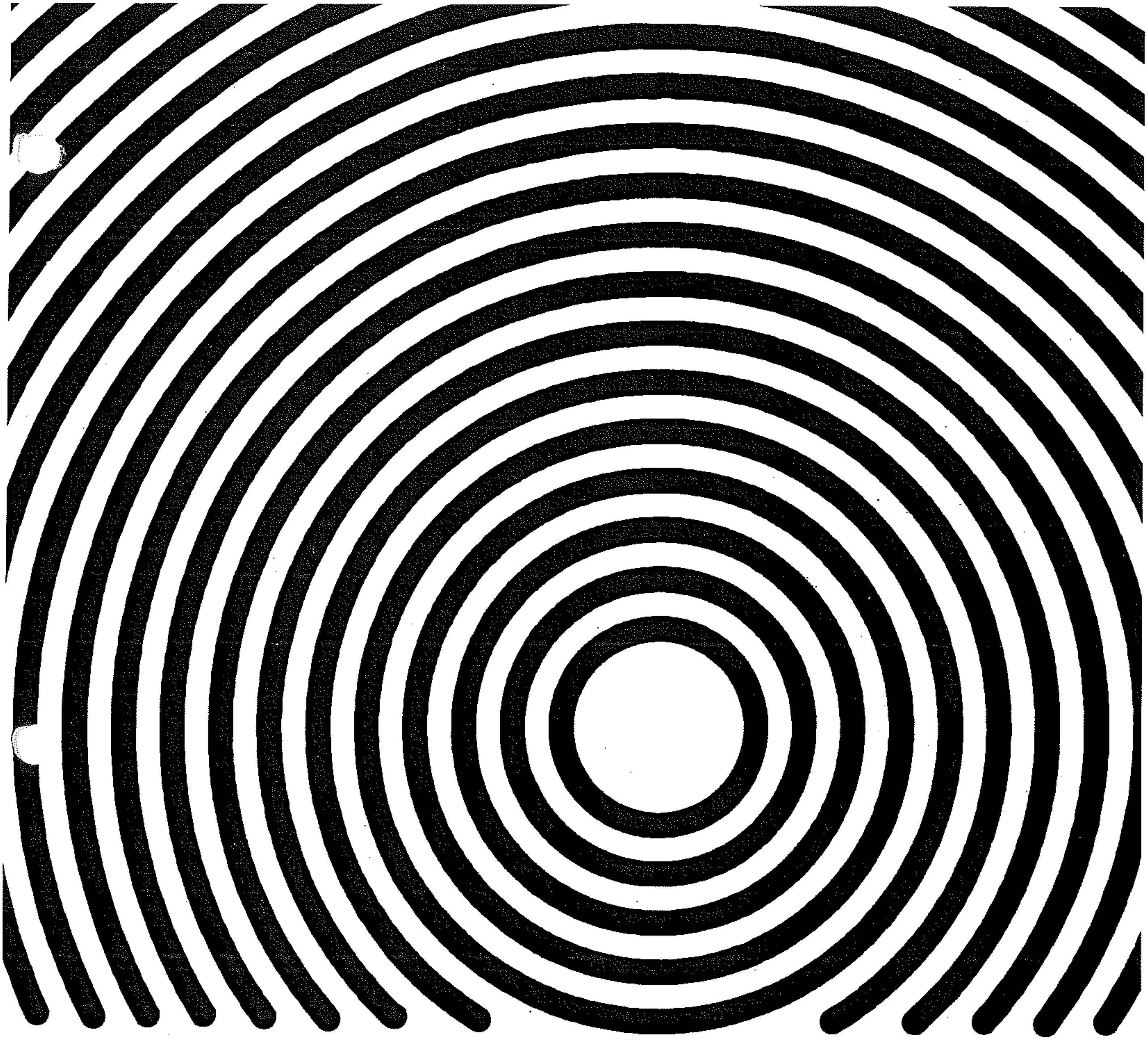


← this first

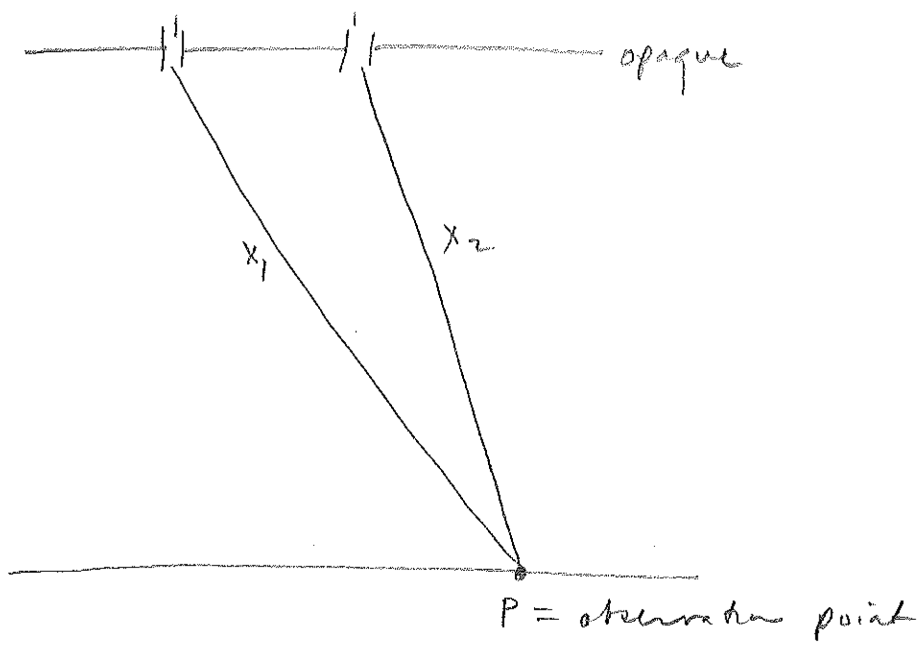
HRK(5e) ← 41-2

Figure 3 An interference pattern produced by water waves in a ripple tank. Two vibrating prongs create two patterns of circular ripples, which overlap to give a pattern of maxima and minima in the waves. The right-hand edge of this photograph plays the role of the screen in Fig. 1. Note that, along





Double slit interference



Total Electric field at P is

$$E_{tot} = E_1 + E_2 = A \sin(\omega t - kx_1) + A \sin(\omega t - kx_2)$$

Interference occurs because path lengths x_1 & x_2 differ, causing a phase difference in the fields.

Let $\Delta x = x_1 - x_2$

$$E_{TOT} = A\sin(\omega t - kx_1) + A\sin(\omega t - kx_1 + \underbrace{k\Delta x}_{\Delta\phi})$$

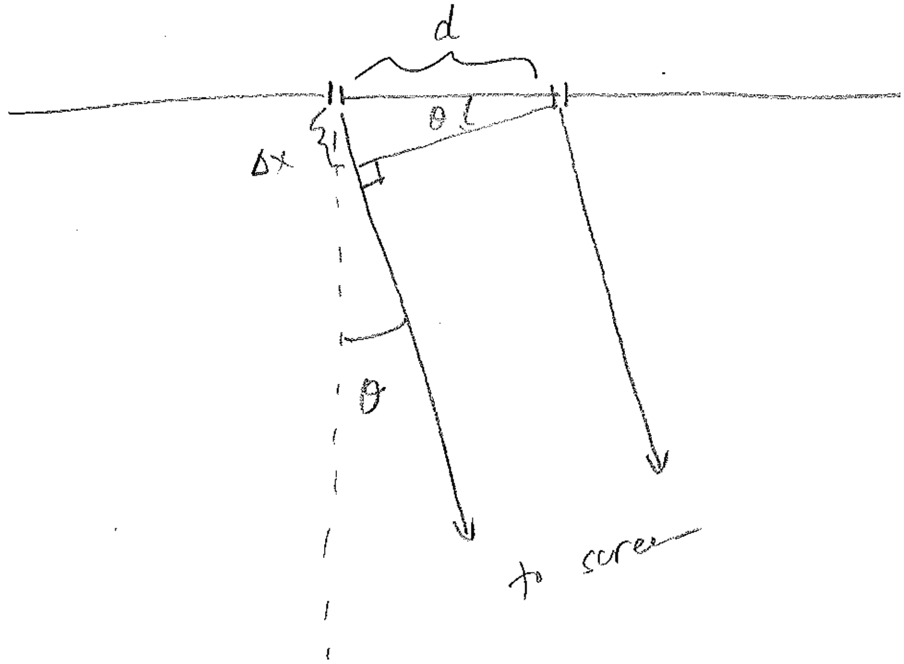
Phase difference between the two waves is

$$\Delta\phi = k\,\Delta x = \frac{2\pi}{\lambda}\Delta x.$$

Constructive interference $\Delta\phi = 2\pi m \Rightarrow \Delta x = m\lambda$

Destructive interference $\Delta\phi = 2\pi(m + \frac{1}{2}) \Rightarrow \Delta x = (m + \frac{1}{2})\lambda$

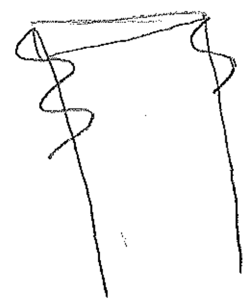
Screen is usually distant compared to distance between slits, so rays are nearly parallel



$\sin\theta = \frac{\Delta x}{d} \Rightarrow \Delta x = d\sin\theta$

For Double slits
Condition for const. interference: $\boxed{d\sin\theta = m\lambda, \quad m = \text{integer}}$

Condition for destructive interference $\boxed{d\sin\theta = (m+\frac{1}{2})\lambda, \quad m = \text{integer}}$



[DEMO: Mark's chains]

$\boxed{\text{Double slit intensity pattern}}$

Recall Poynting: $\vec{S} = \epsilon_0 c^2 \vec{E} \times \vec{B}$

$$|\vec{S}| = \epsilon_0 c |\vec{E}|^2$$

$$E_{tot} = A_{tot} \sin(\omega t + \dots)$$

$$|\vec{S}_{tot}|^2 = \epsilon_0 c A_{tot}^2 \sin^2(\omega t + \dots)$$

Intensity = time average of $|\vec{S}|$

but time average of $\sin^2(\omega t + \dots) = \frac{1}{2}$

$$I = \frac{1}{2}\epsilon_0 c A_{tot}^2$$

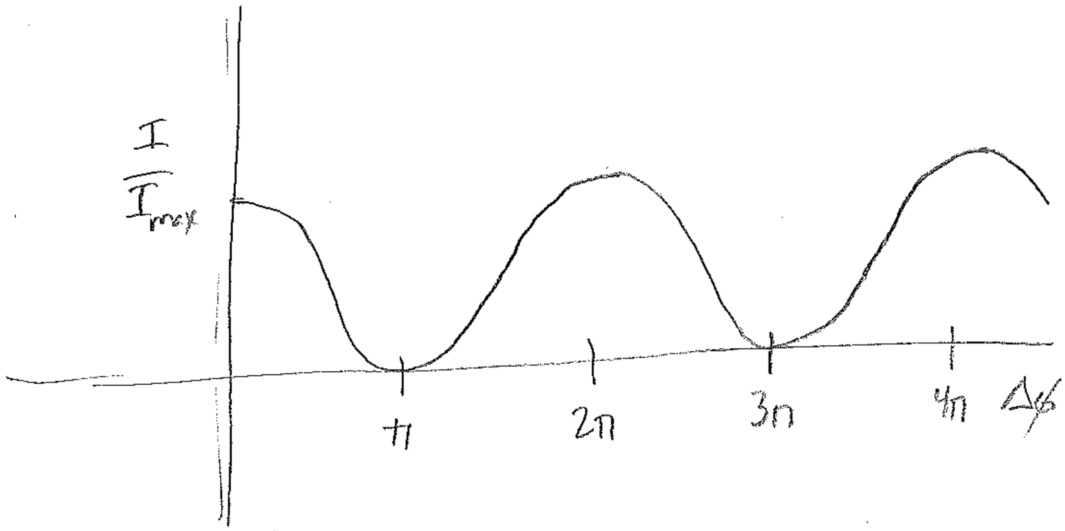
Recall $A_{tot} = 2A \cos\left(\frac{\Delta\phi}{2}\right)$

$$I = \frac{1}{2}\epsilon_0 c \left(2A \cos\frac{\Delta\phi}{2}\right)^2$$

A_{tot} is maximized for $\Delta\phi = 0$ (constructive) and so is I.

$$I_{max} = \frac{1}{2}\epsilon_0 c (2A)^2$$

$$\frac{I}{I_{max}} = \cos^2\left(\frac{\Delta\phi}{2}\right)$$



Now $\Delta\phi = k\,\Delta x = \left(\frac{2\pi}{\lambda}\right)(d\sin\theta)$

$$\frac{I}{I_{max}} = \cos^2\left(\frac{2\pi d}{\lambda}\sin\theta\right)$$