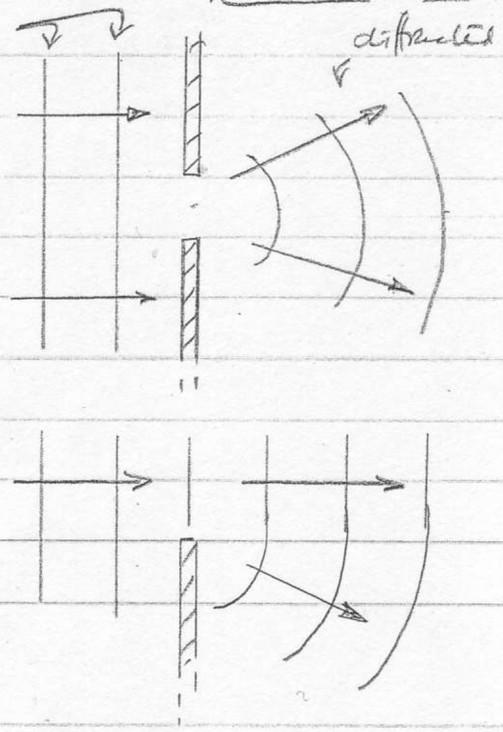
Diffraction – Single gap. 1/3

1. Basic – GCSE

Any set of waves will be diffracted – spread out – when passing through a gap or by an obstacle.
Diffraction is strongest when the obstacle is about the same size as the wavelength.

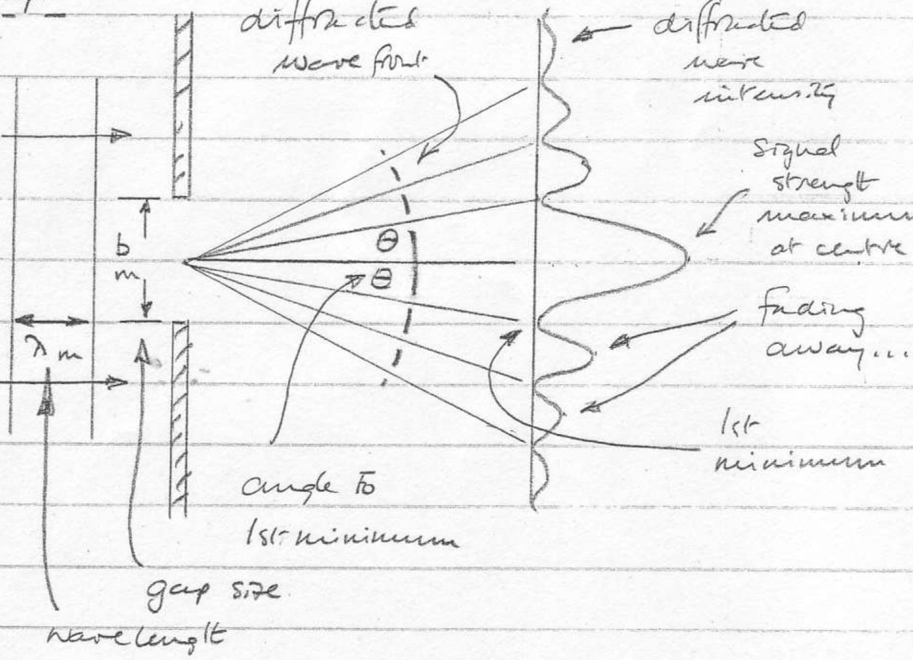


2. Advanced – Single gap

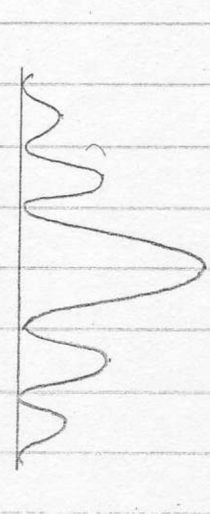
The wave front is not smoothly diffracted – the signal strength varies between maximum + minimum (effectively zero.)

For the 1st minimum...

$$\sin\theta = \frac{\lambda}{b}$$



the pattern shows the intensity variation for radiation, wavelength λ m and gap width b m
Sketch the pattern for ...
– radiation of same wavelength
– but half the gap width.



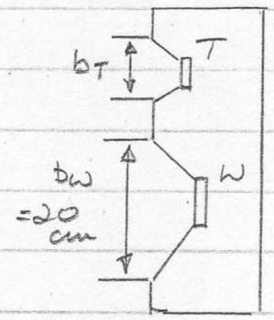
TJN
02.01

Diffraction - Single gap - examples {2/3}   AS Physics

Aerials and loudspeakers behave like gaps, through which the radio/sound energy radiates

1. Loudspeakers $V_{sound\ in\ air} = 330\ m/s$

The woofer emits sound of frequency 2 kHz.



Woofer - low f

Tweeter - high f

a) Calculate the sound λ.

b) Calculate the angle of the first minimum

c) Calculate the angle of the "cone" of sound

d) sketch the pattern of the 2 kHz sound waves

e) If the woofer were to emit high frequency sounds of 10 kHz, what would be the 1st minimum angle now?

f) Sketch the pattern of the 10 kHz waves from woofer W.

g) In a real (decent) speaker the high frequency sounds are emitted by a Tweeter T.

What diameter should the tweeter have for a total "cone" angle of 90° ?

TJN
02.01

Diffraction - examples {3/3}

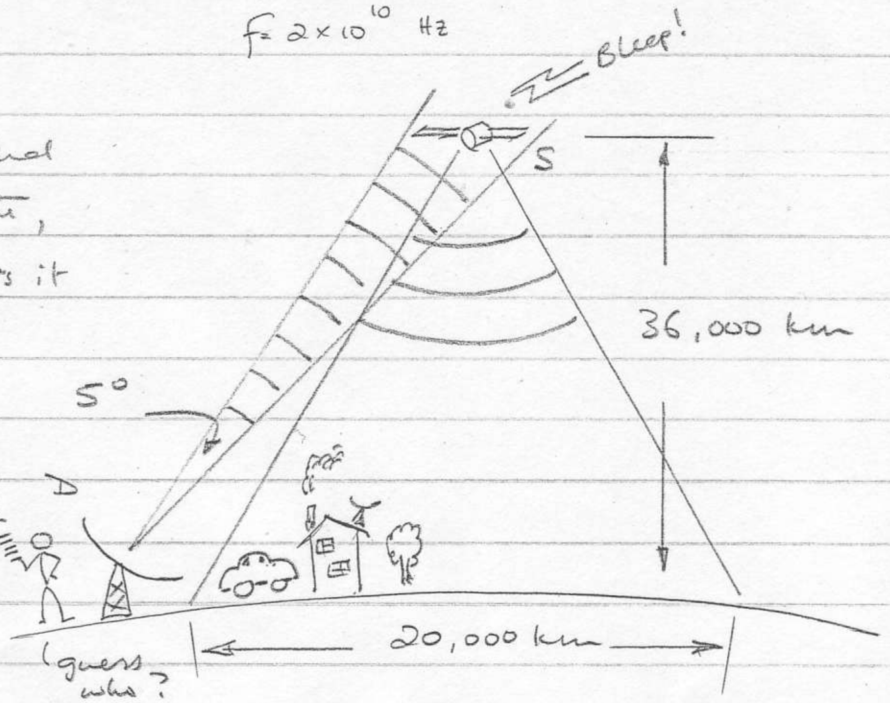
AS Physics

1. Satellites, aerials

"SKY" want to transmit their TV signal to their ASTRA satellite, which then re-broadcasts it back to subscribers on Earth.

The dish aerial D must produce a narrow signal so most of the energy gets to the satellite

$f = 2 \times 10^{10}$ Hz



v radio waves $= 3 \times 10^8$ m/s

a) If the Total beam angle must be 5°, what must be the diameter of dish D?

b) The satellite signal must reach an area 20,000 km across on Earth.

Calculate what size aerial the satellite needs for this.

MN
02.01

Diffraction – Single Gap – Answers

AS Physics

page 1

→ Same λ....

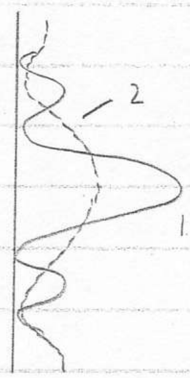
– half gap width

so $\sin\theta = \lambda / \tfrac{b}{2} = 2 \times \frac{\lambda}{b}$

and less radiation gets through

so central peak – about 2× as wide

– about ½ as high.



page 2 Loudspeaker

a) $V = f\lambda \Rightarrow \lambda = V/f = 330/2000 = 0.165$ m (1) (1) (2

b) angle ... $\sin\theta = \lambda/b$ (1) $= 0.165/0.2$ ← in m!

$= 0.825$ → angle $\theta = \sin^{-1} 0.825 = 55.6^\circ$ (1) (2

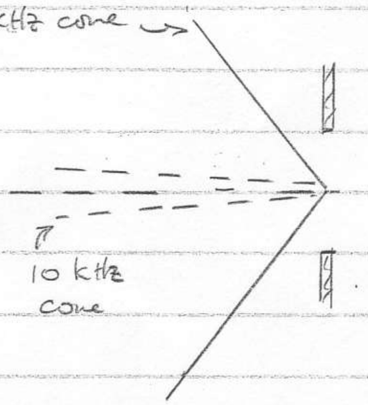
c) angle of "cone of sound" = (1

$= 2 \times \theta = 2 \times 55.6^\circ$

$= 111^\circ$ (1)

(d) (1)

(f) (1).



(e) for 10 kHz .... $\lambda = V/f = 330/10\,000 = 0.033$ m (1)

so $\sin\theta = \lambda/b = 0.033/0.2 = 0.165$ (1)

angle to 1st min. $\theta = 9.5^\circ$ (1) (3

g) Cone angle of 90° → 1st min angle $= 45$ (1)

so $\sin\theta = \sin 45 = \lambda/b$ (1) → $b = \lambda/\sin 45 = 0.033/0.707 = 0.047$ m $= 4.7$ cm

(3

page 3 Satellite

a) total beam angle = 5° so 1st min. angle $\theta = 2.5^\circ$ (1)

$\sin\theta = \sin 2.5 = \lambda/b \Rightarrow b = \lambda/\sin\theta$

So $b = 0.015/\sin 2.5 = 0.34$ m (1)

so aerial D must be 0.34 m (34 cm) across

λ of 2×10^{10} Hz signal

$\lambda = V/f$ (1) $= \dfrac{3 \times 10^8}{2 \times 10^{10}}$

$= 0.015$ m (1) (4

b) for satellite ... 1st min angle θ... $\sin\theta = \dfrac{10\,000 \text{ km}}{36\,000 \text{ km}}$ (1) $= 0.278$ (1)

$\sin\theta = \dfrac{\lambda}{b} \rightarrow b = \lambda/\sin\theta = \dfrac{0.015}{0.278}$ (1) $= 0.054$ m

$\theta = 16^\circ$ but you don't need this (3

So satellite aerial is 0.054 m (5.4 cm) across

Satellite /7

/14

Loud speaker

MN

3.04