

## 2.1 Wave propagation

Slides: Video 2.1.5 Diffraction from periodic structures

Text reference: Quantum Mechanics for Scientists and Engineers

Section B.4





# Wave propagation

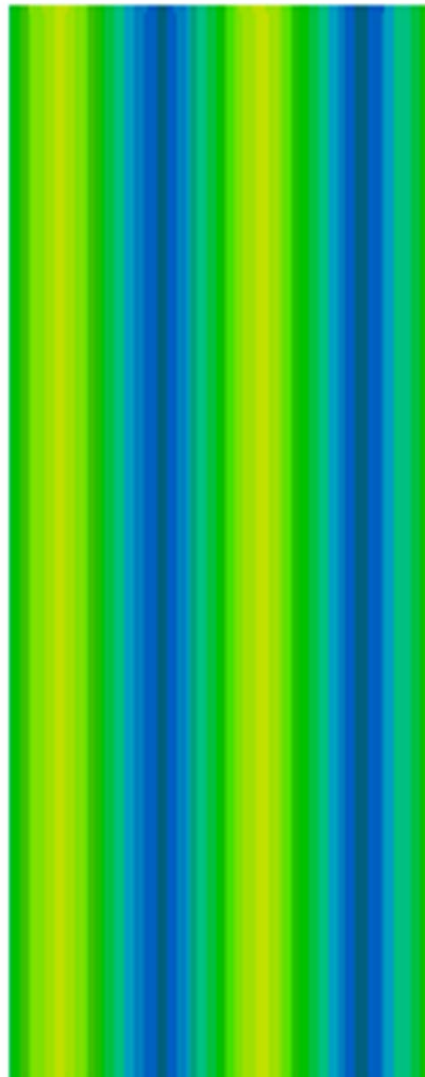
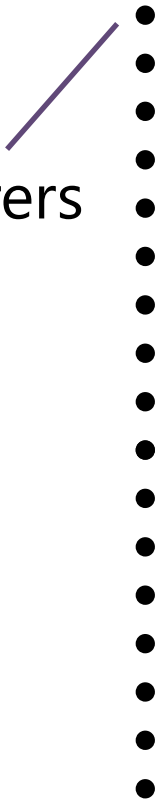


Diffraction from periodic structures

Quantum mechanics for scientists and engineers

David Miller

Scatterers



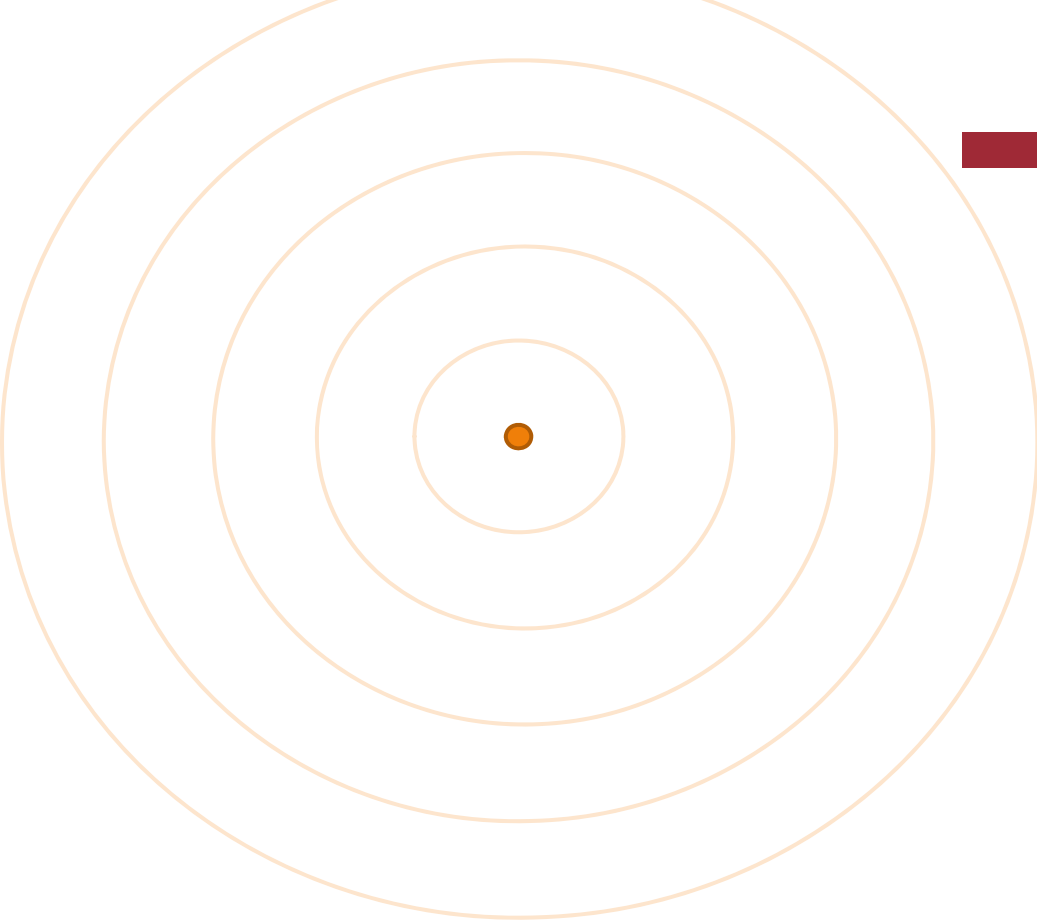
## Periodic structures

Suppose we have a set of  
equally spaced identical  
scatterers

and we shine a  
monochromatic wave at  
them from the right  
what does the back-  
scattered light look like?

# Periodic structures

One scatterer will give a set  
of phase fronts  
concentric "circles"

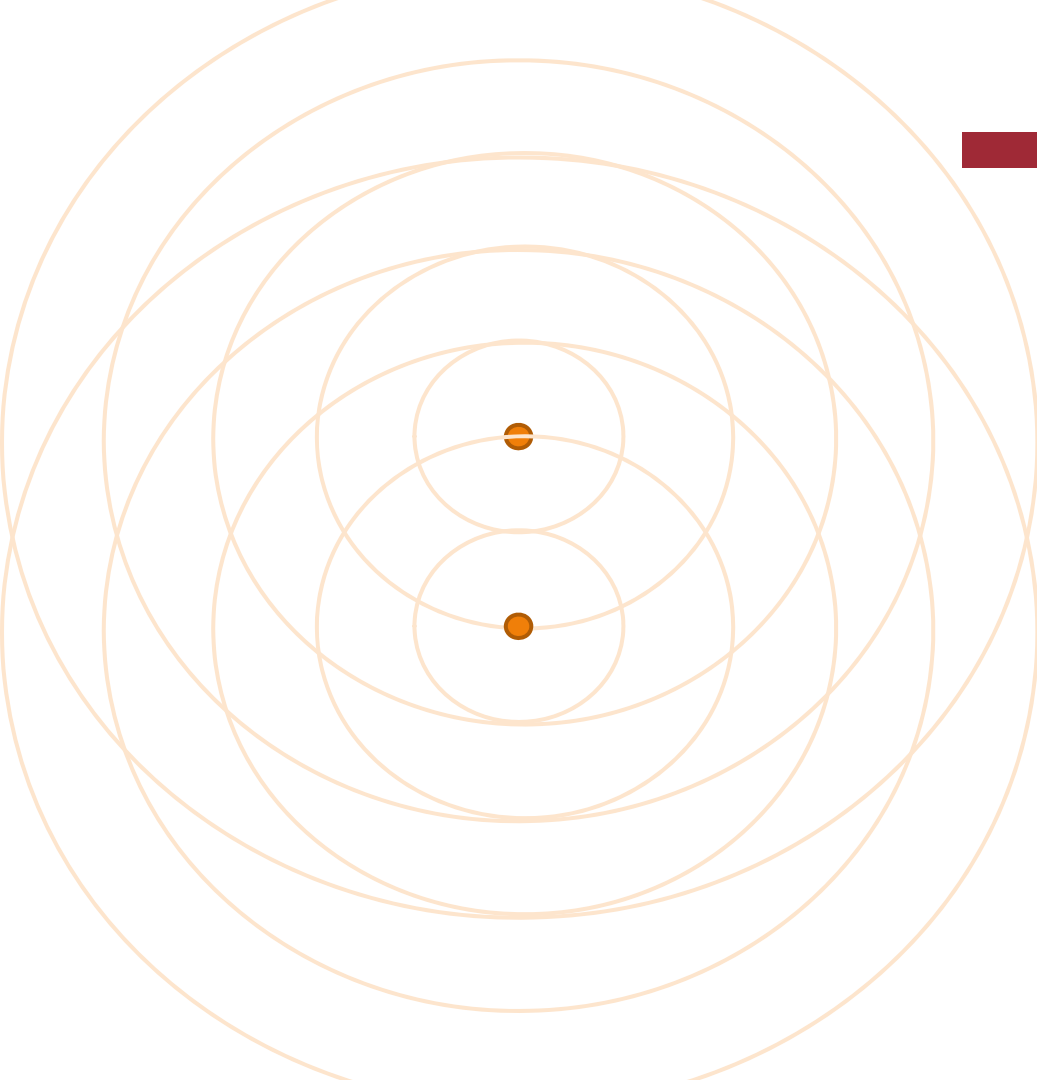


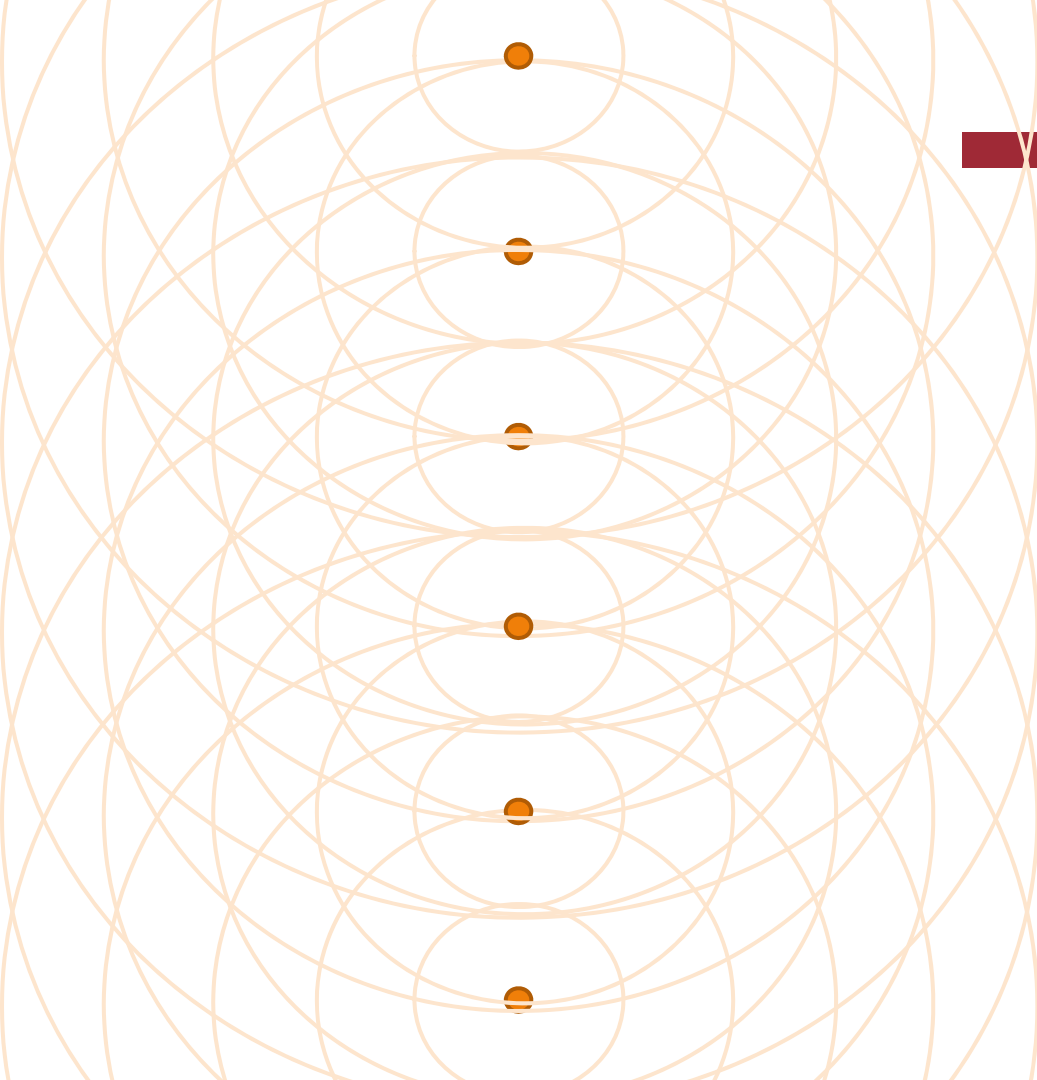
# Periodic structures

One scatterer will give a set  
of phase fronts

concentric “circles”

Two will give two sets  
which will interfere





## Periodic structures

One scatterer will give a set of phase fronts

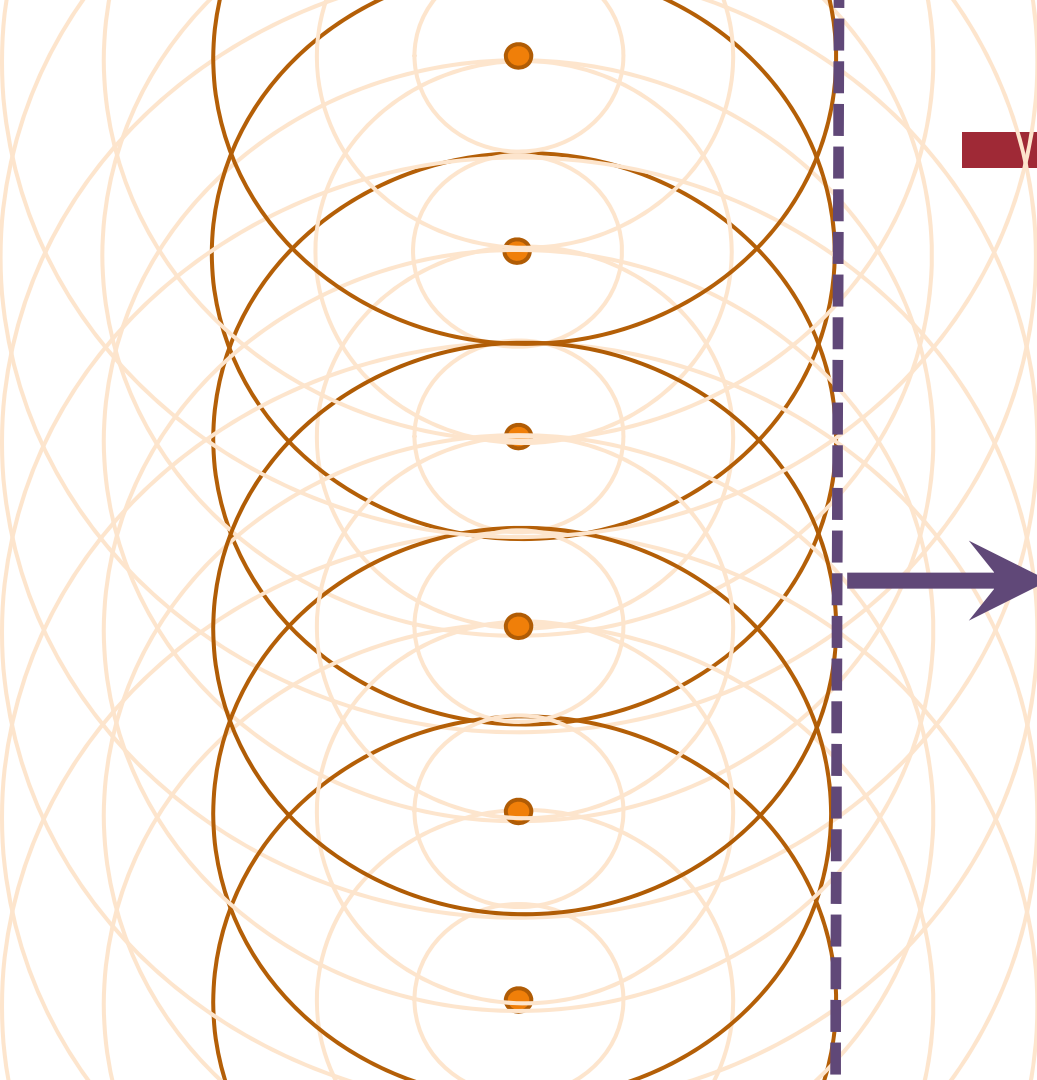
concentric “circles”

Two will give two sets

which will interfere

Multiple equally spaced scatterers give multiple sets

# Periodic structures

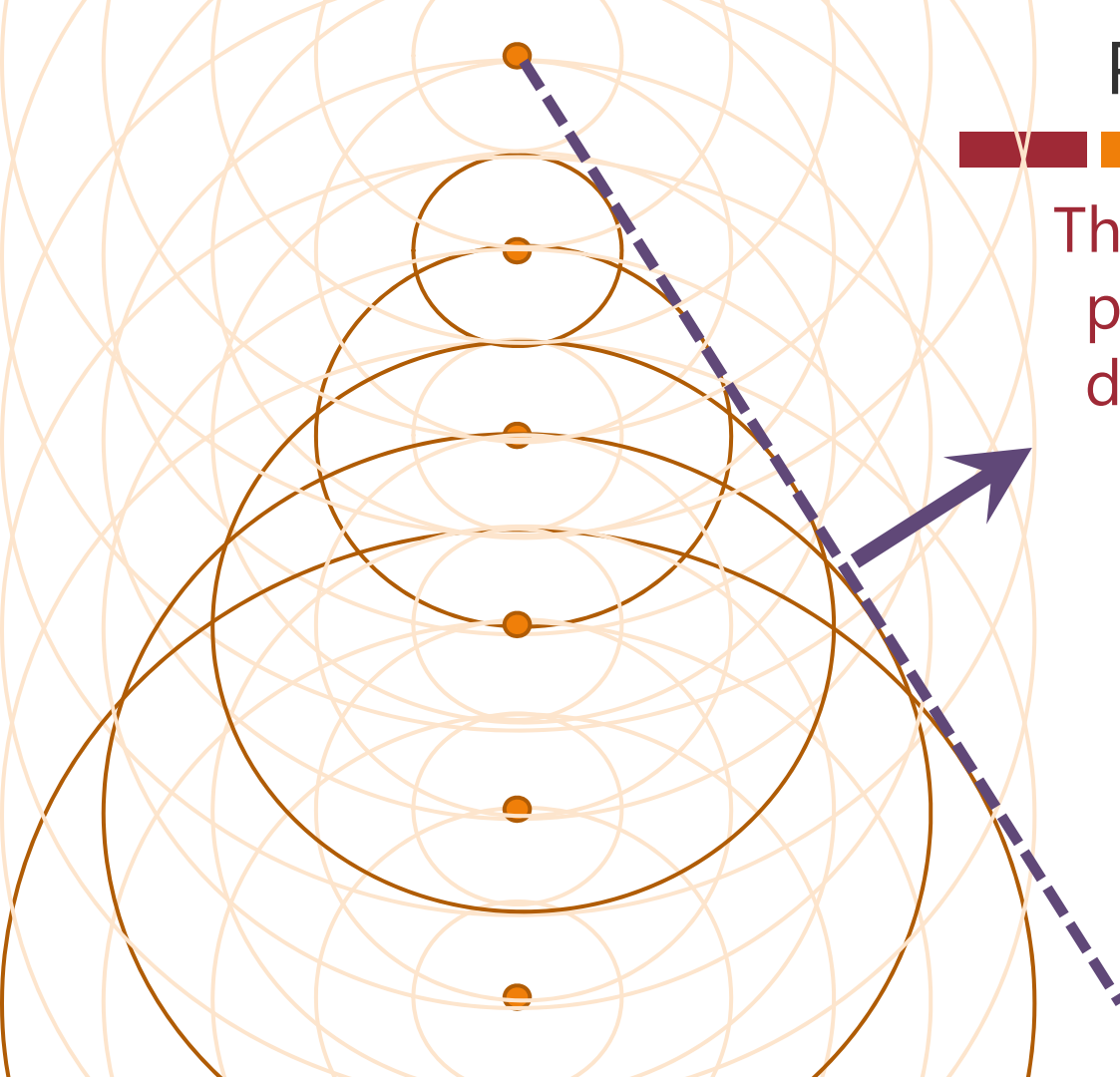


The diagram illustrates the concept of periodic structures and diffraction. On the left, a vertical array of seven orange dots represents scatterers. Concentric orange circles centered on these dots represent wavefronts. A vertical dashed blue line is positioned to the right of the dots. A solid blue arrow points from the dashed line towards the right, indicating the direction of wave propagation or observation.

These scatterers all add in phase for particular directions, here  
"straight ahead"  
called a "zeroth order" diffraction



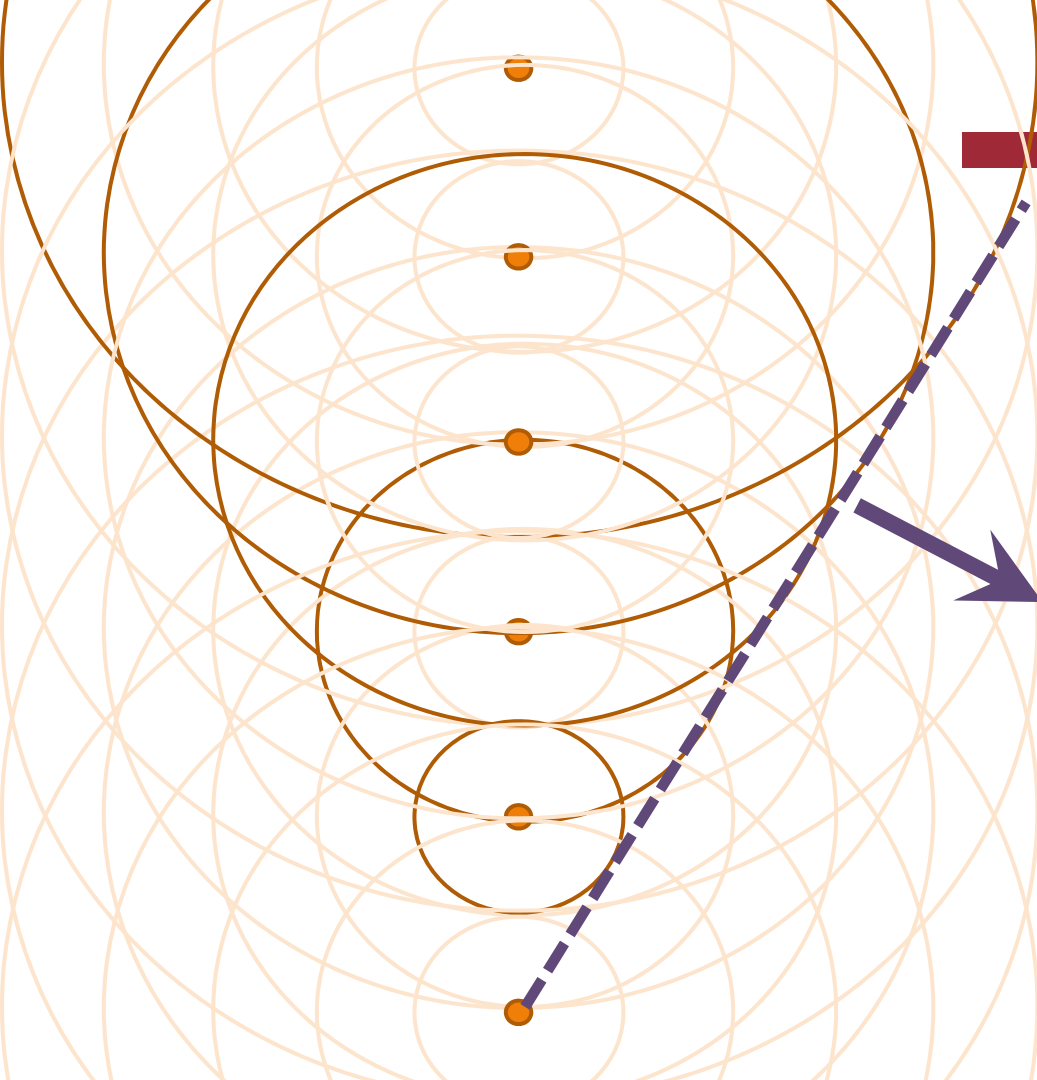
# Periodic structures



These scatterers all add in phase for particular directions, here  
"straight ahead"  
called a "zeroth order"  
diffraction  
an upward direction



# Periodic structures



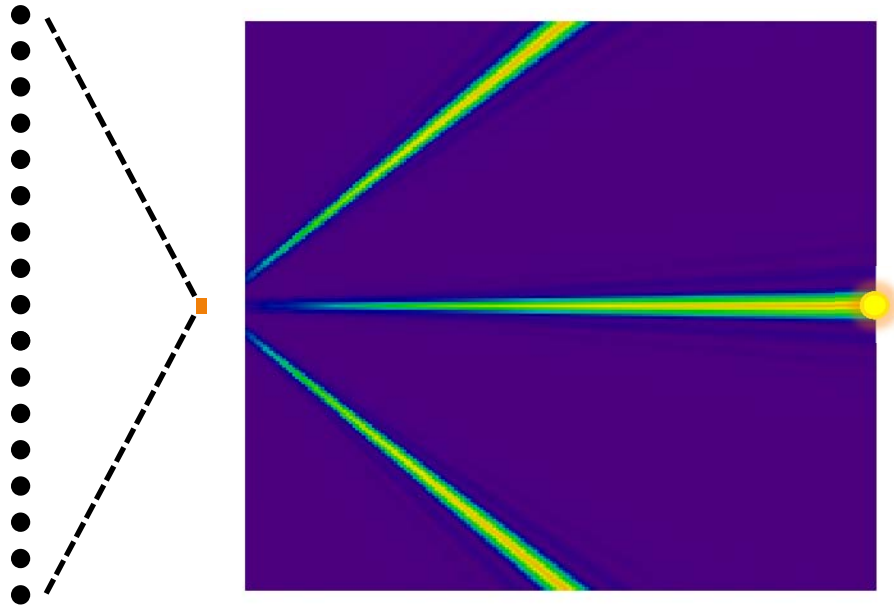
The diagram illustrates wave interference from a periodic structure. It features a vertical column of six orange dots representing scatterers. Concentric circles centered on these dots represent wavefronts. A dashed blue line with an arrow points upwards and to the right, passing through the centers of the dots, representing a direction of constructive interference (zeroth order). Other dashed blue lines with arrows point in different directions, representing other possible diffraction orders.

These scatterers all add in phase for particular directions, here

“straight ahead”  
called a “zeroth order”  
diffraction

an upward direction  
a downward direction

# Periodic structures



Scatterer spacing  
in wavelengths

1.5

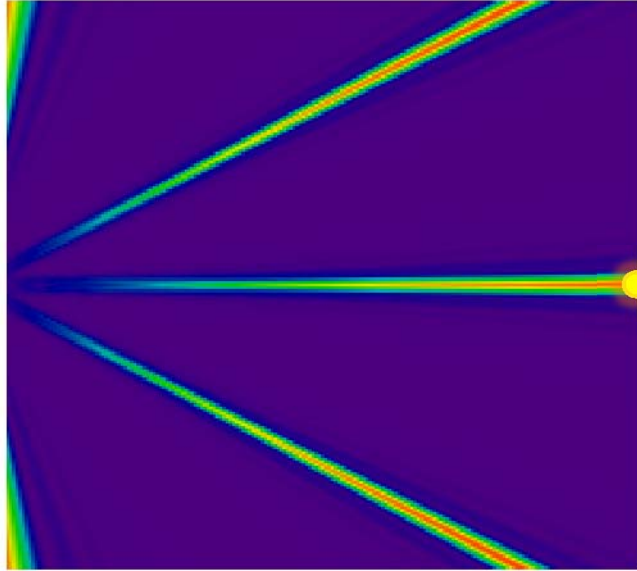
At large distances from the scatterer

we get a multiple-beam  
diffraction pattern

which looks like a set of  
points on a screen

Larger scatterer separation  
gives beams closer in angle

# Periodic structures



Scatterer spacing  
in wavelengths

2.0

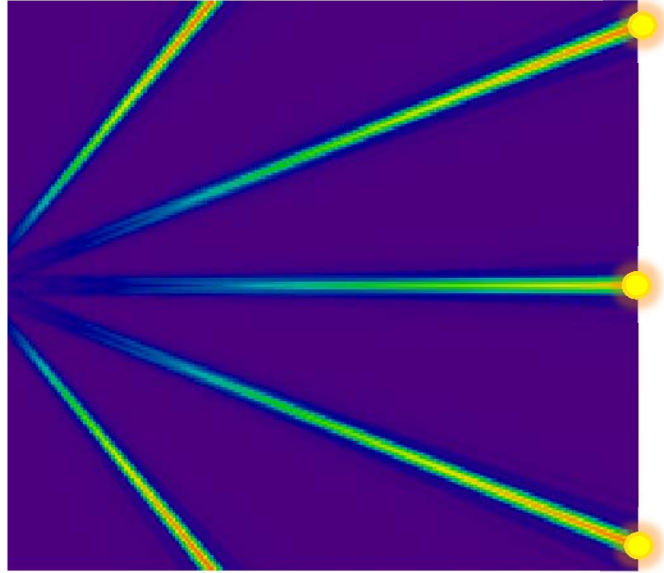
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# Periodic structures



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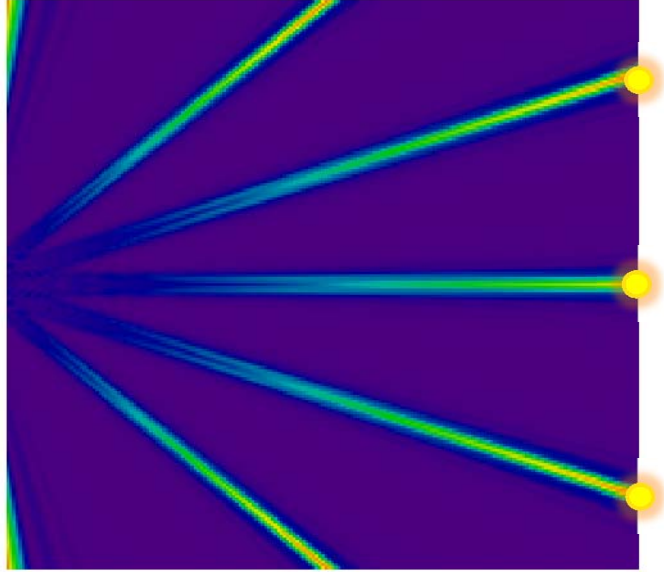
which looks like a set of points on a screen

Larger scatterer separation gives beams closer in angle

Scatterer spacing  
in wavelengths

2.5

# Periodic structures



Scatterer spacing  
in wavelengths

3.0

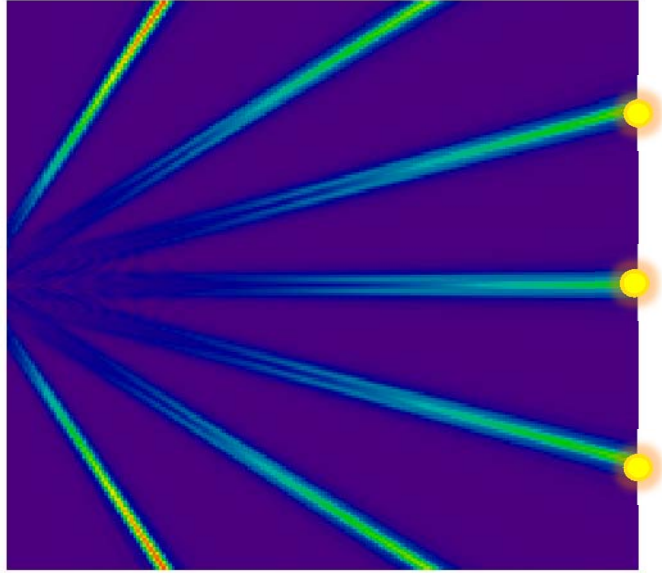
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# Periodic structures



Scatterer spacing  
in wavelengths

3.5

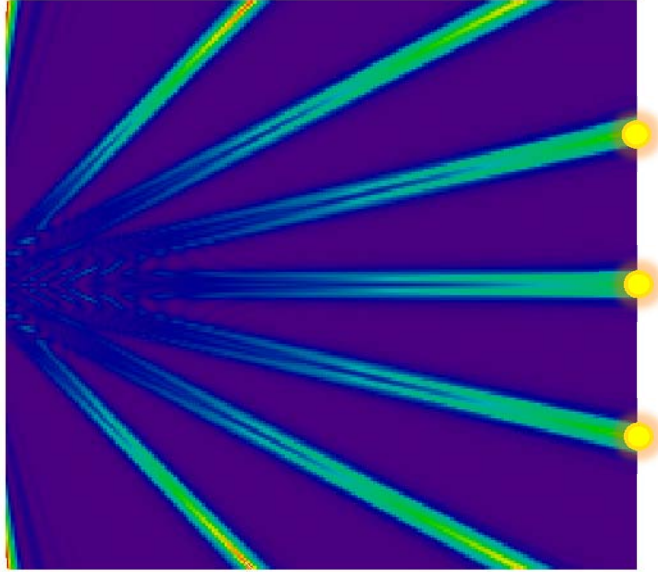
At large distances from the scatterer

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Larger scatterer separation  
gives beams closer in angle

# Periodic structures



Scatterer spacing  
in wavelengths

4.0

At large distances from the scatterer

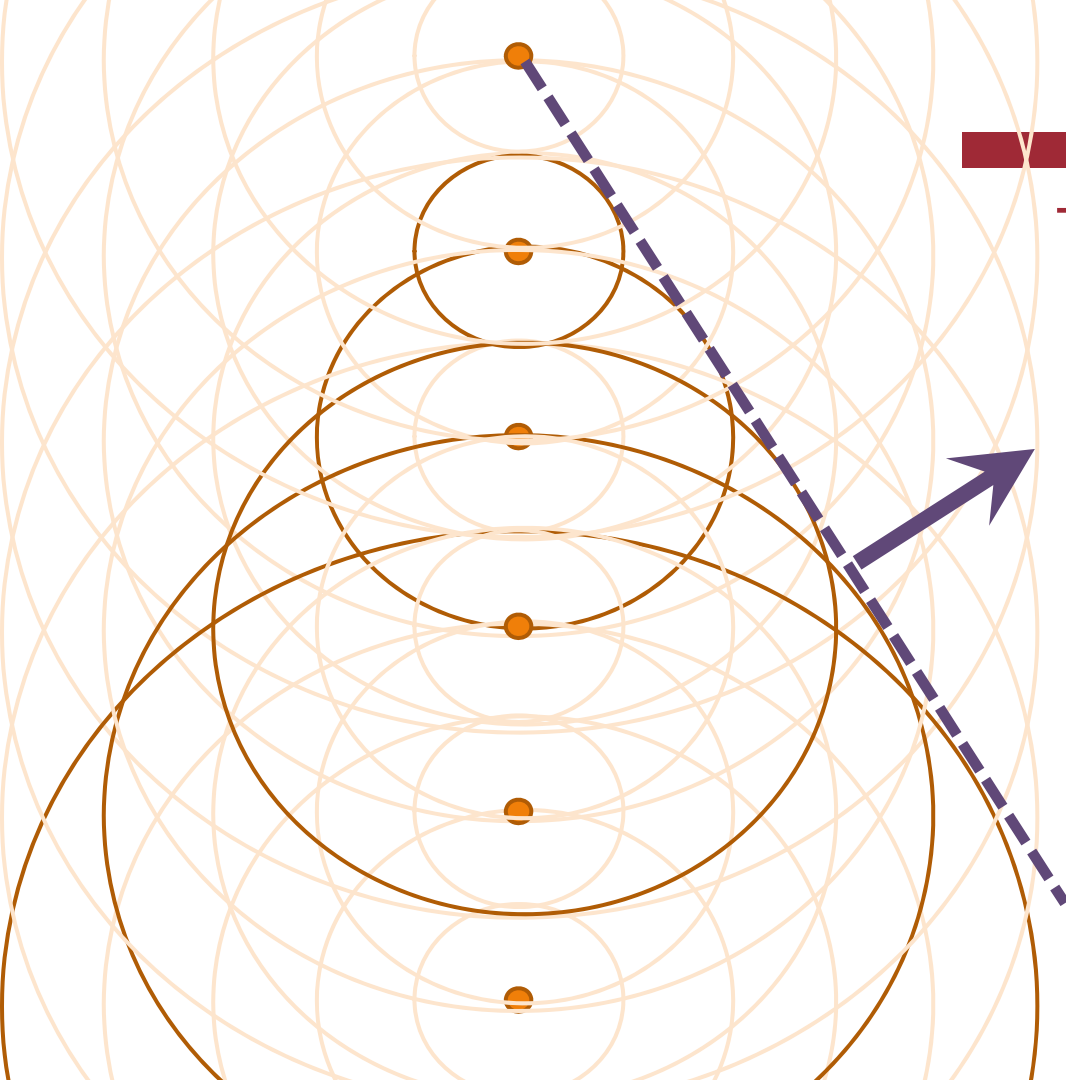
we get a multiple-beam  
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Larger scatterer separation  
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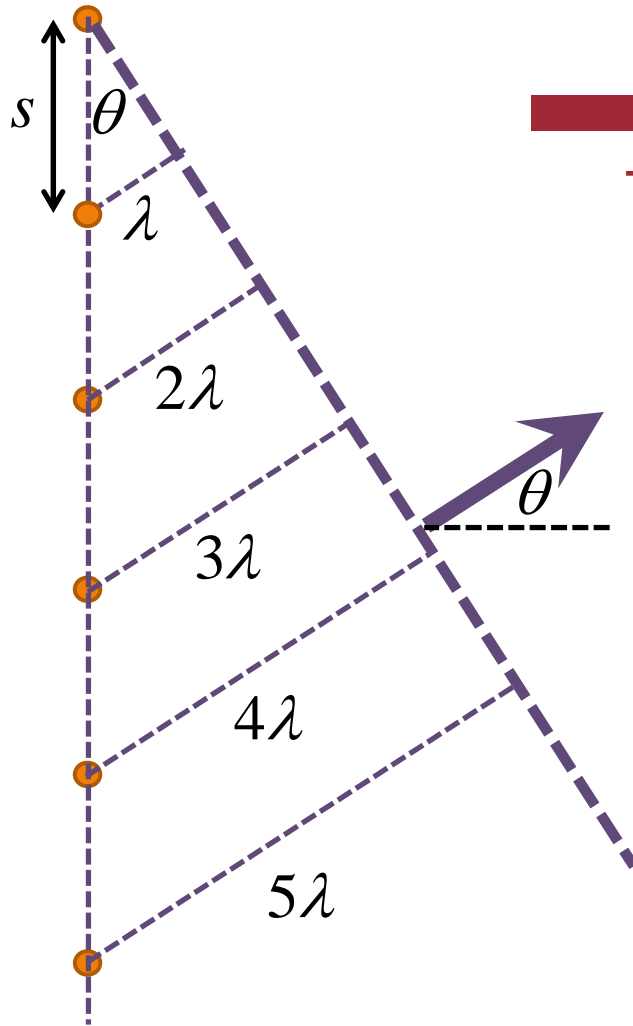


# Periodic structures



The angle  $\theta$  of these  
diffracted waves  
is given by simple  
geometry

# Periodic structures



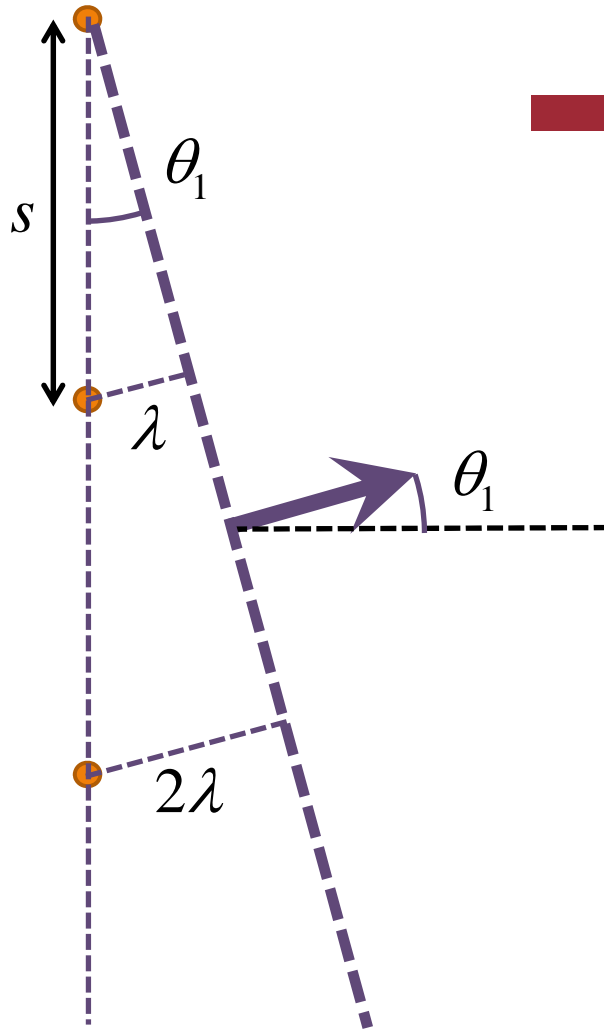
The angle  $\theta$  of these diffracted waves is given by simple geometry

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

where

$\lambda$  is the wavelength  
 $s$  is the separation between scatterers

# Periodic structures

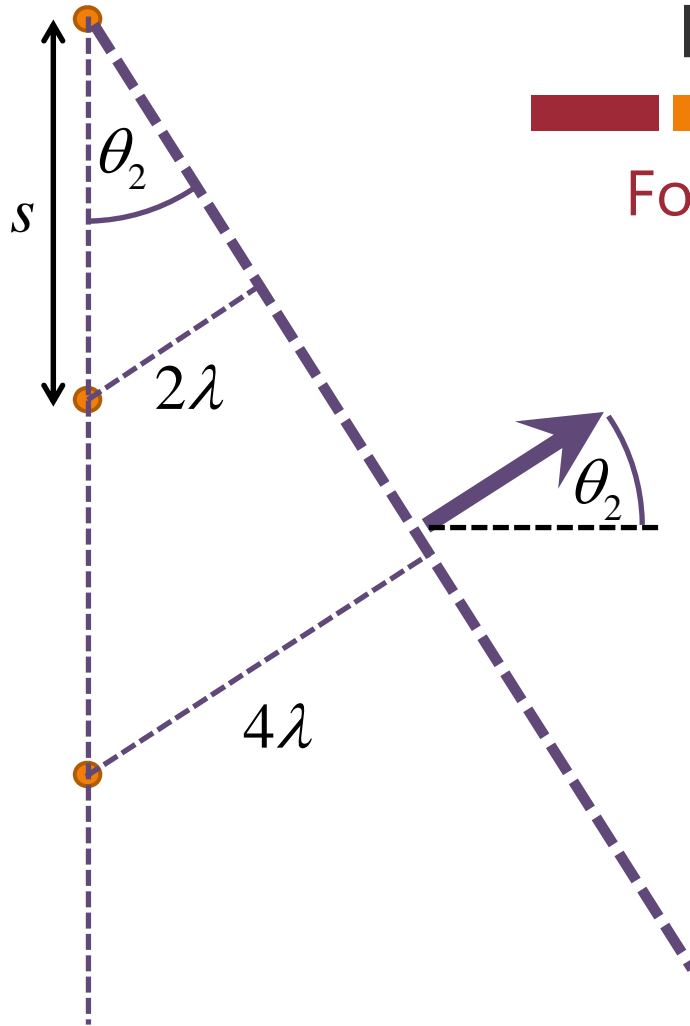


For larger spacings  $s$   
multiple diffraction  
"orders" are possible

$$\sin \theta_1 = \frac{\lambda}{s}$$

is a "first order"  
diffraction

# Periodic structures

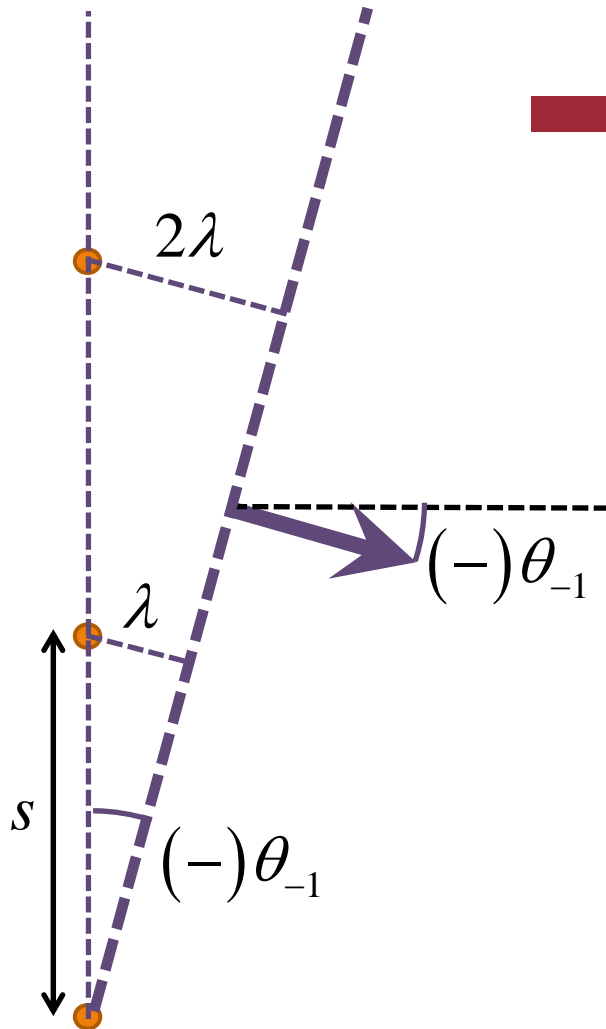


For larger spacings  $s$   
multiple diffraction  
"orders" are possible

$$\sin \theta_2 = \frac{2\lambda}{s}$$

is a "second order"  
diffraction

# Periodic structures



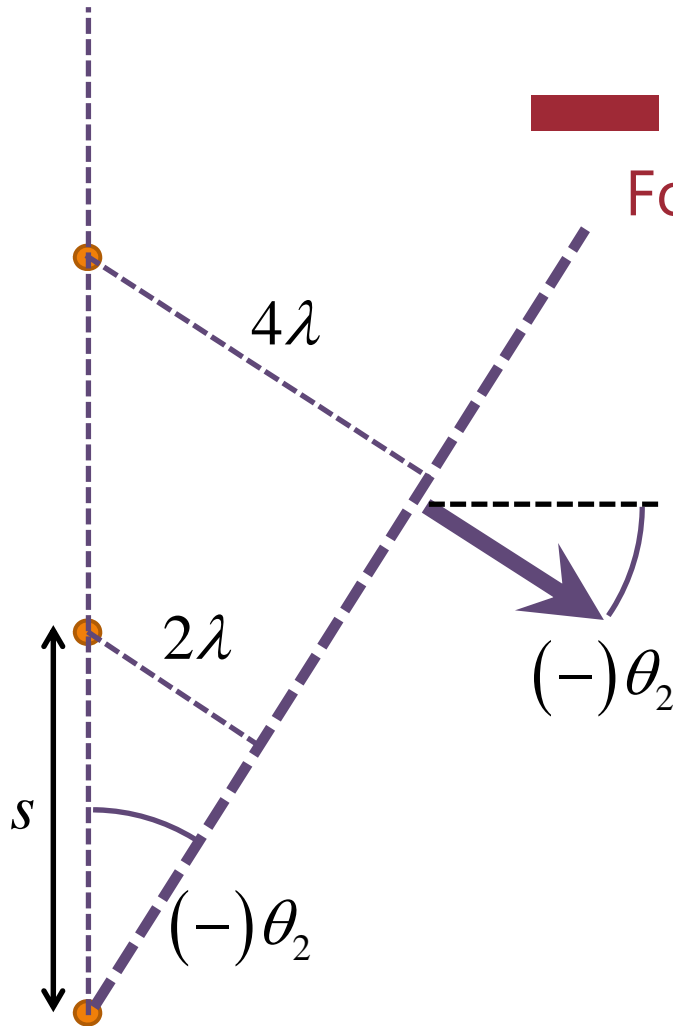
For larger spacings  $s$   
multiple diffraction  
“orders” are possible

$$\sin \theta_{-1} = \frac{(-)\lambda}{s}$$

is a “(negative) first  
order” diffraction

the sign is a matter  
of taste for this  
“normal” incidence

# Periodic structures



For larger spacings  $s$   
multiple diffraction  
"orders" are possible

$$\sin \theta_{-2} = \frac{(-)2\lambda}{s}$$

is a "(negative) second  
order" diffraction

the sign is a matter  
of taste for this  
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