EM waves
(and teaching online)

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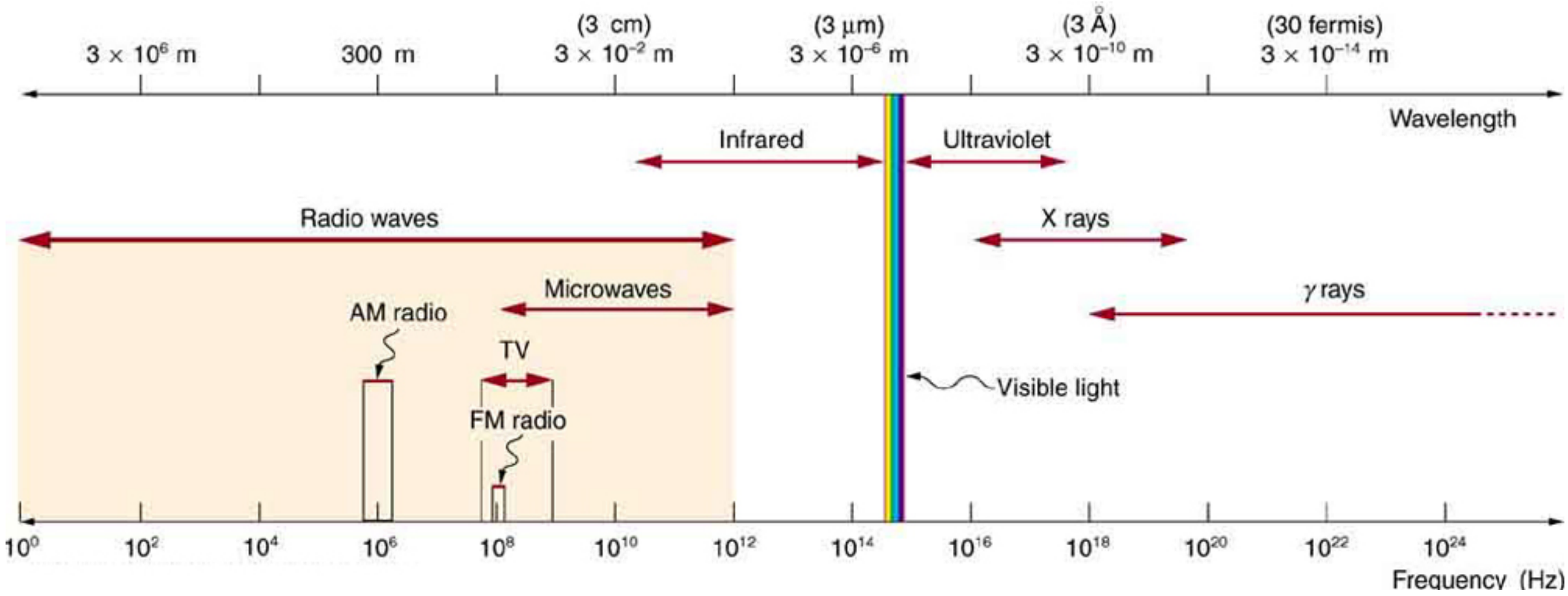
FSU Quarknet 2020 — Thursday July 23rd

$$c = 3 \times 10^8 \text{ m/s}$$



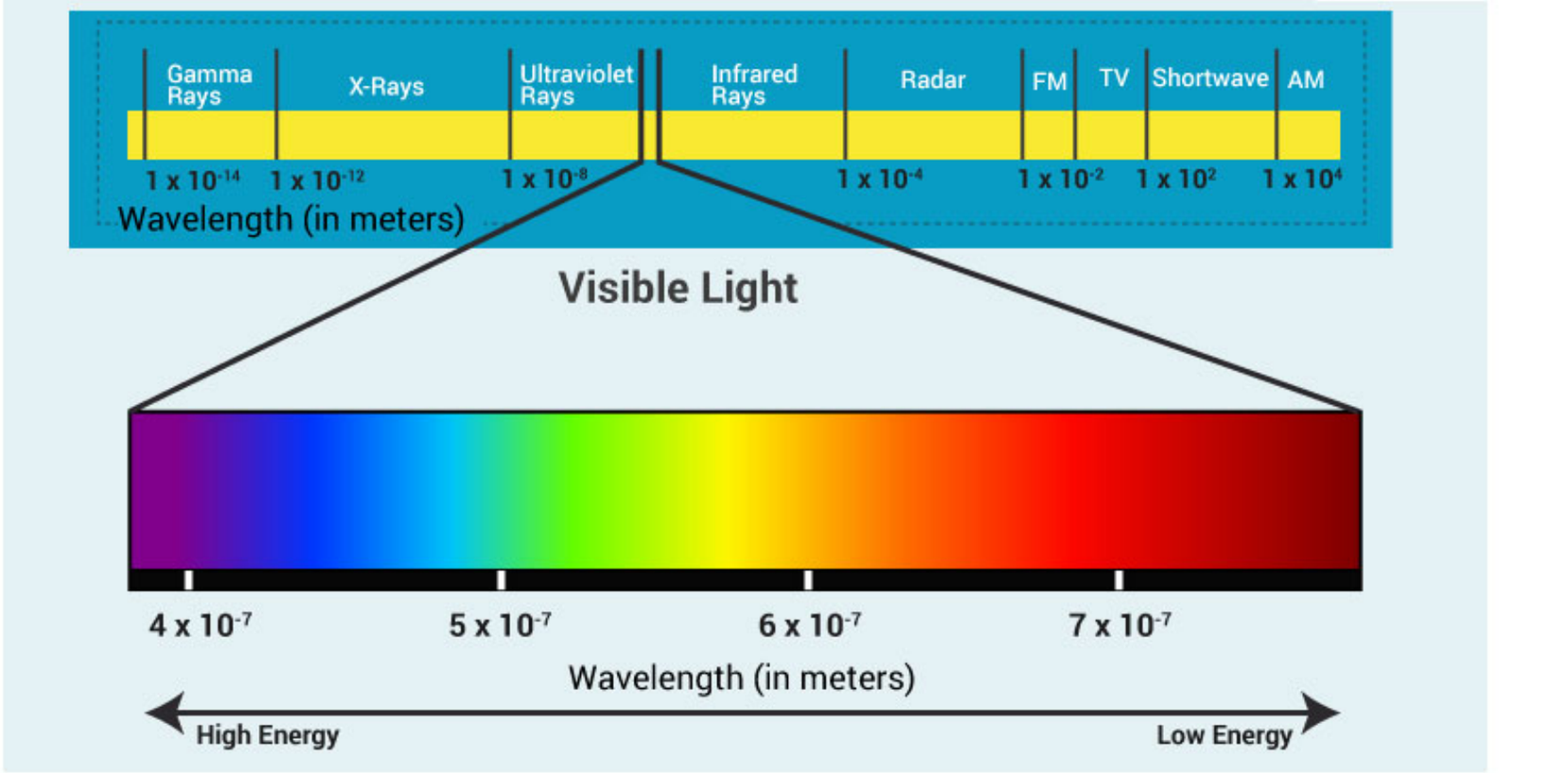
Why are our eyes adapted to see the visible part of the spectrum instead of radio waves, x-rays, or something else?

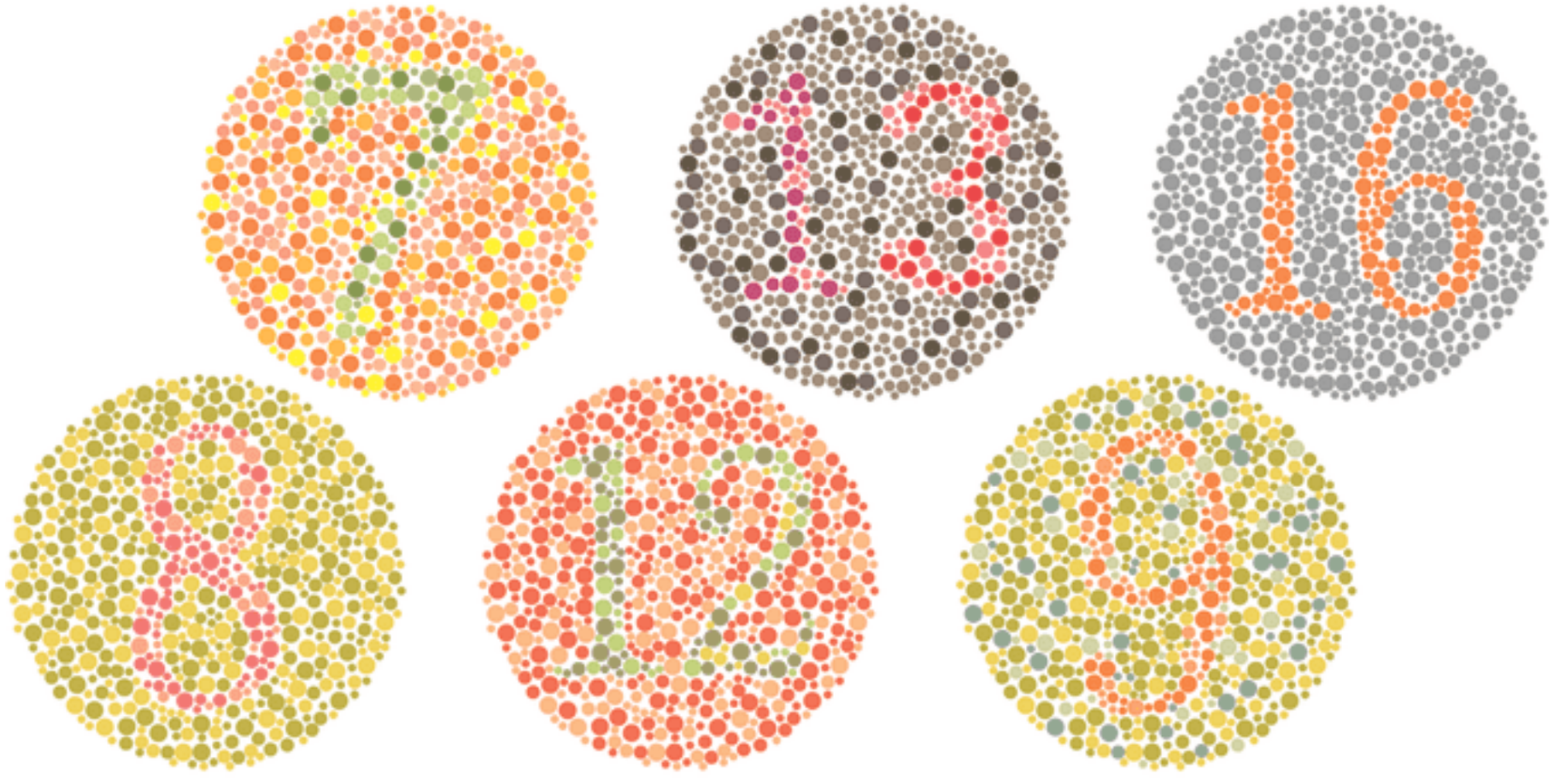
A. It is an accident of evolution and easily could be different.

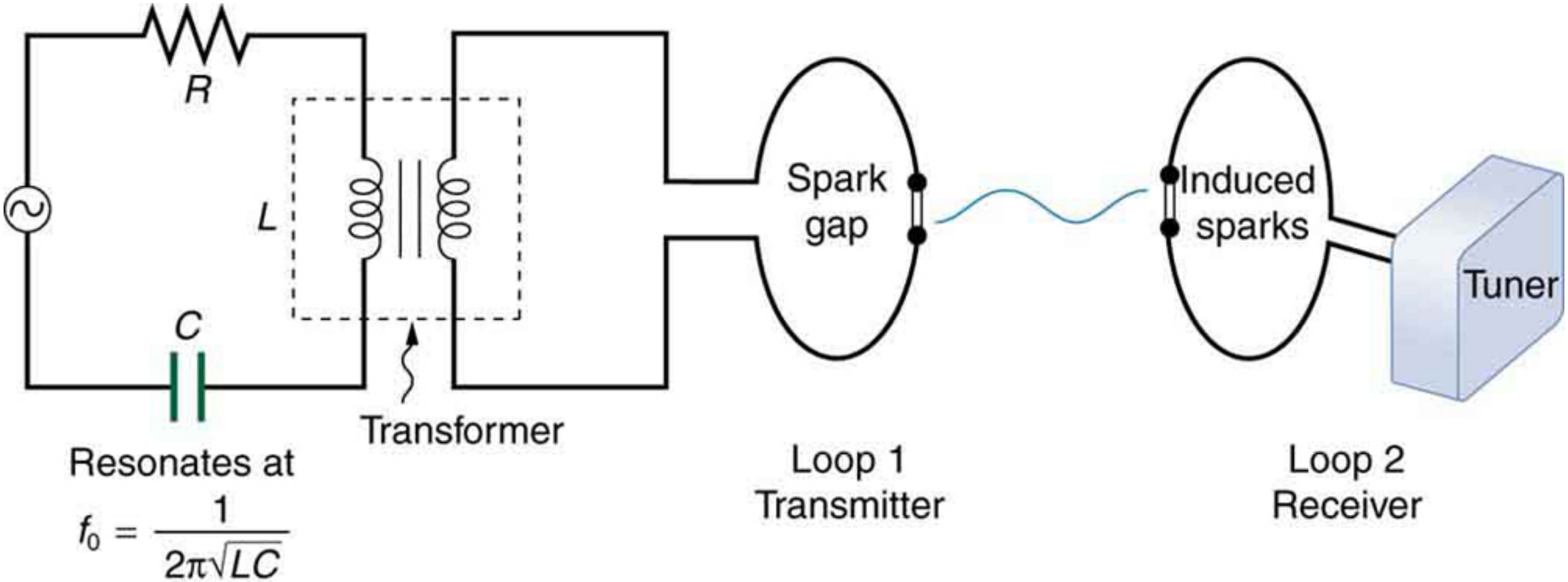
B. The other frequencies of light are too easily absorbed by the atmosphere to be useful.

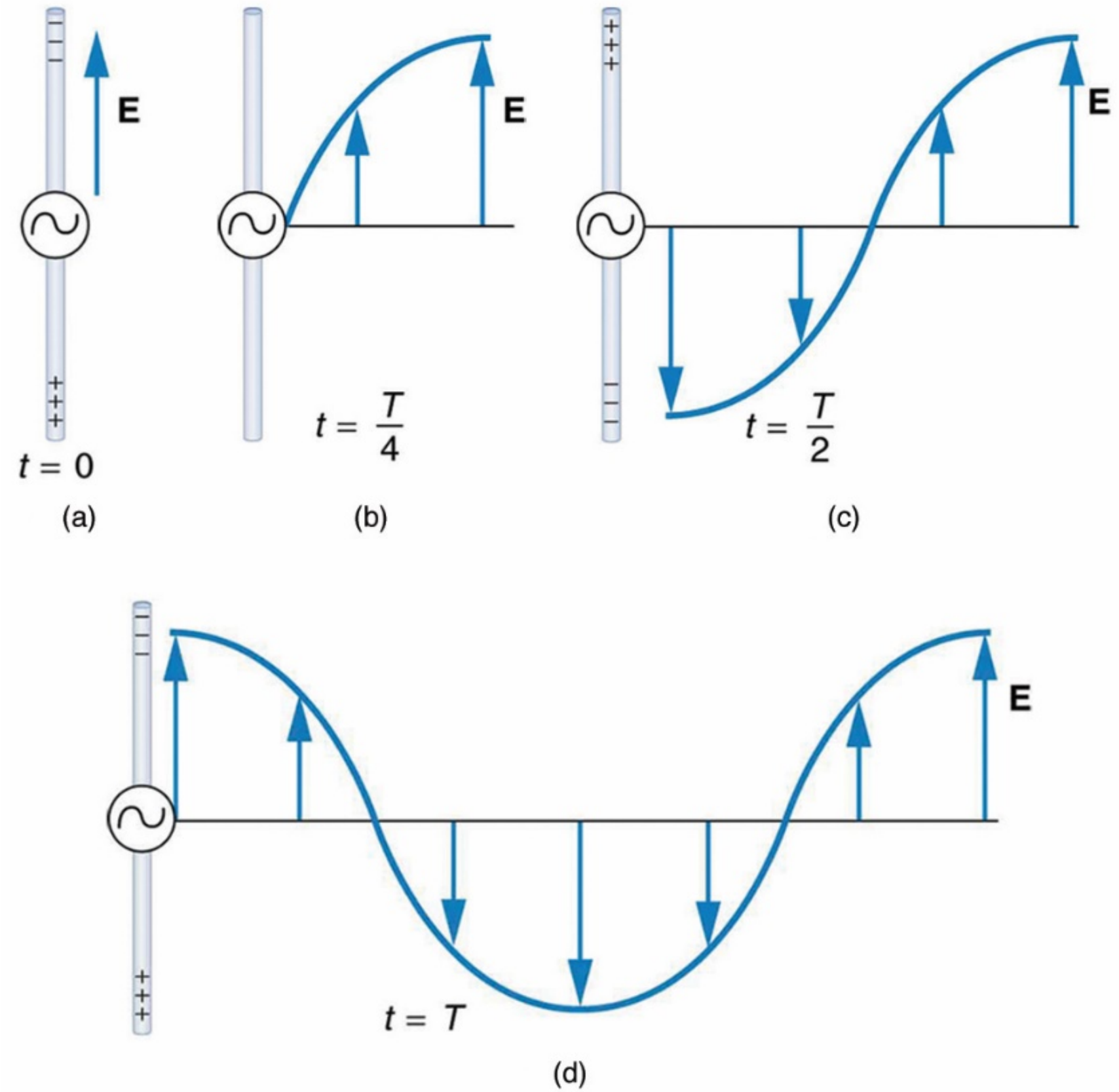
C. Visible light has the appropriate velocity to be detected by biological systems.

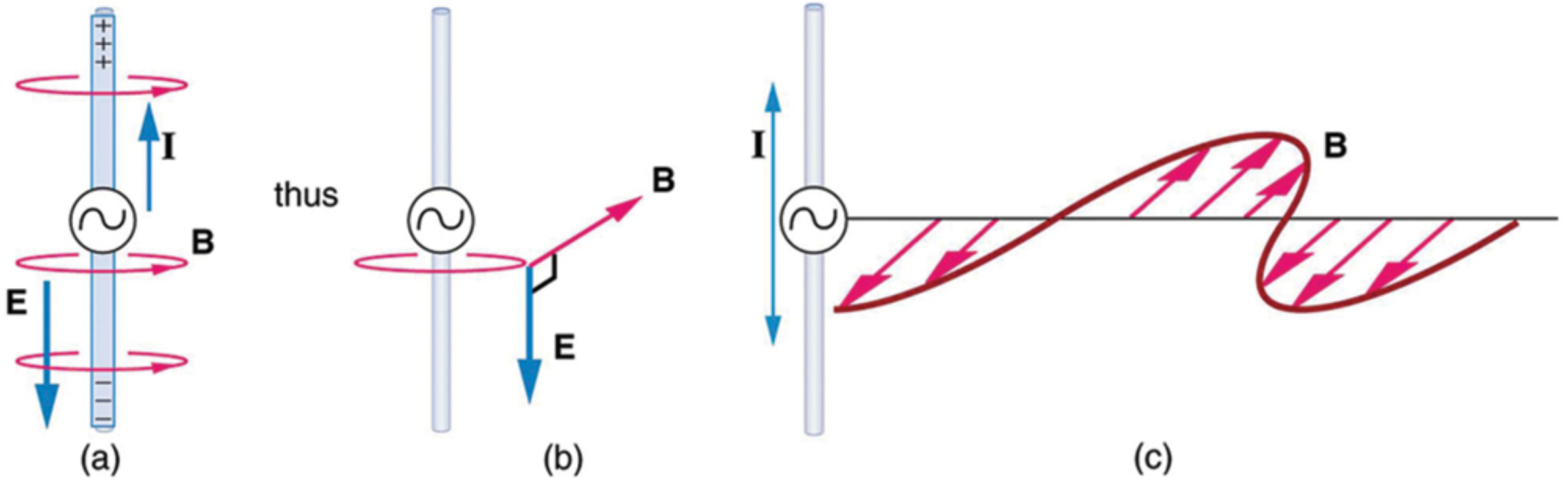
D. The sun emits mostly visible light.


BYJU'S
The Learning App
Gamma Rays
X-Rays
Ultraviolet Rays
Infrared Rays
Radar
FM
TV
Shortwave
AM
1 x 10-14
1 x 10-12
1 x 10-8
1 x 10-4
1 x 10-2
1 x 102
1 x 104
Wavelength (in meters)
Visible Light
4 x 10-7
5 x 10-7
6 x 10-7
7 x 10-7
Wavelength (in meters)
High Energy
Low Energy

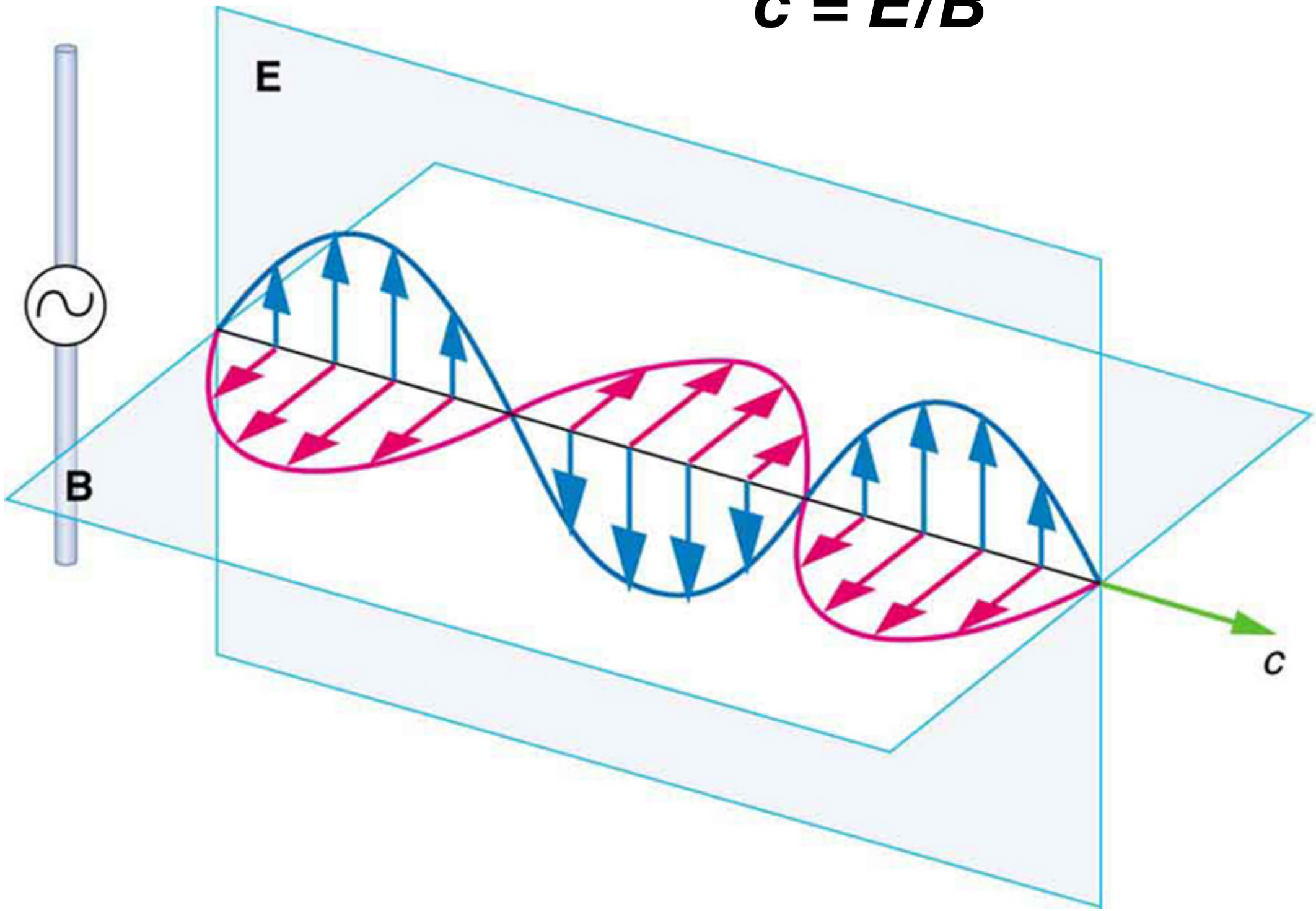


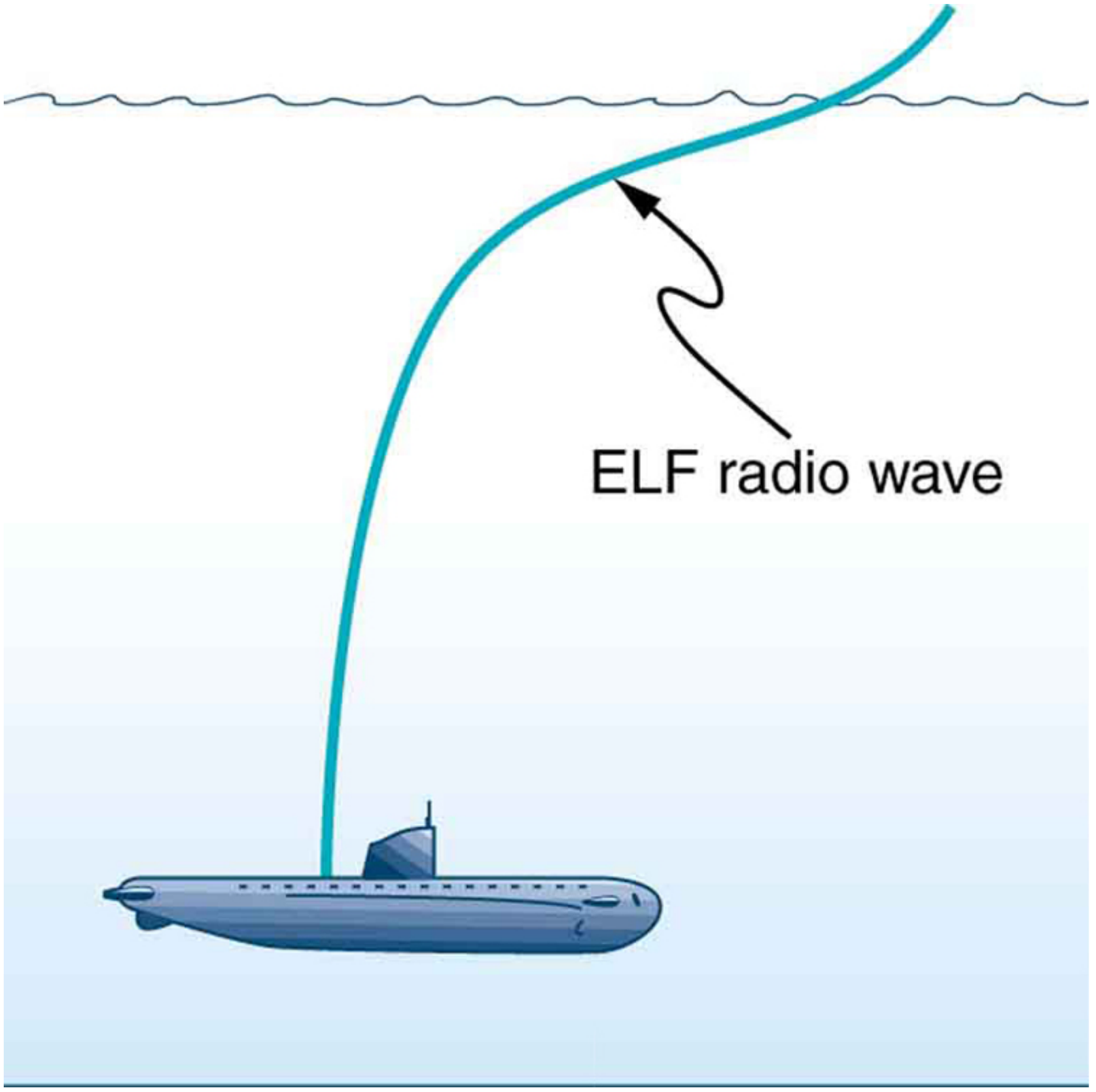

R
L
C
Transformer
Resonates at
$f_0 = \frac{1}{2\pi\sqrt{LC}}$
Spark gap
Loop 1
Transmitter
Induced sparks
Tuner
Loop 2
Receiver

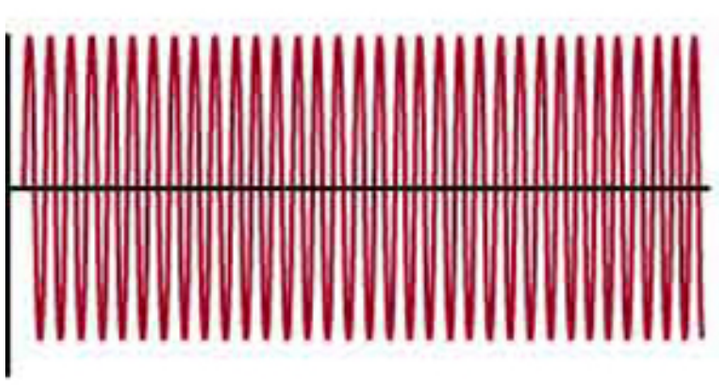

E
t = 0
(a)
E
t = T/4
(b)
E
t = T/2
(c)
E
t = T
(d)


I
B
E
(a)
thus
B
E
(b)
I
B
(c)

$$c = E/B$$

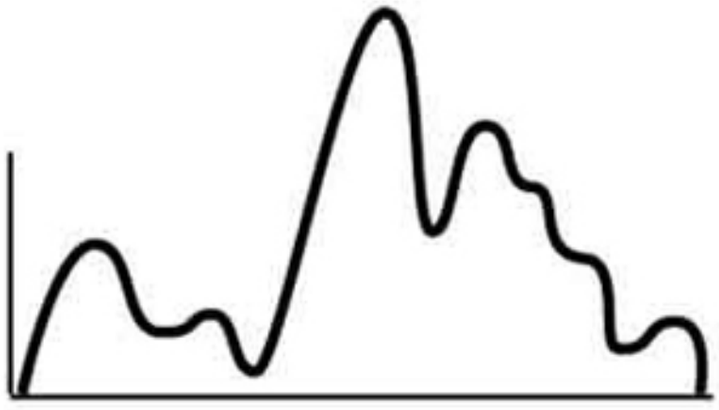



ELF radio wave



Carrier

(a)

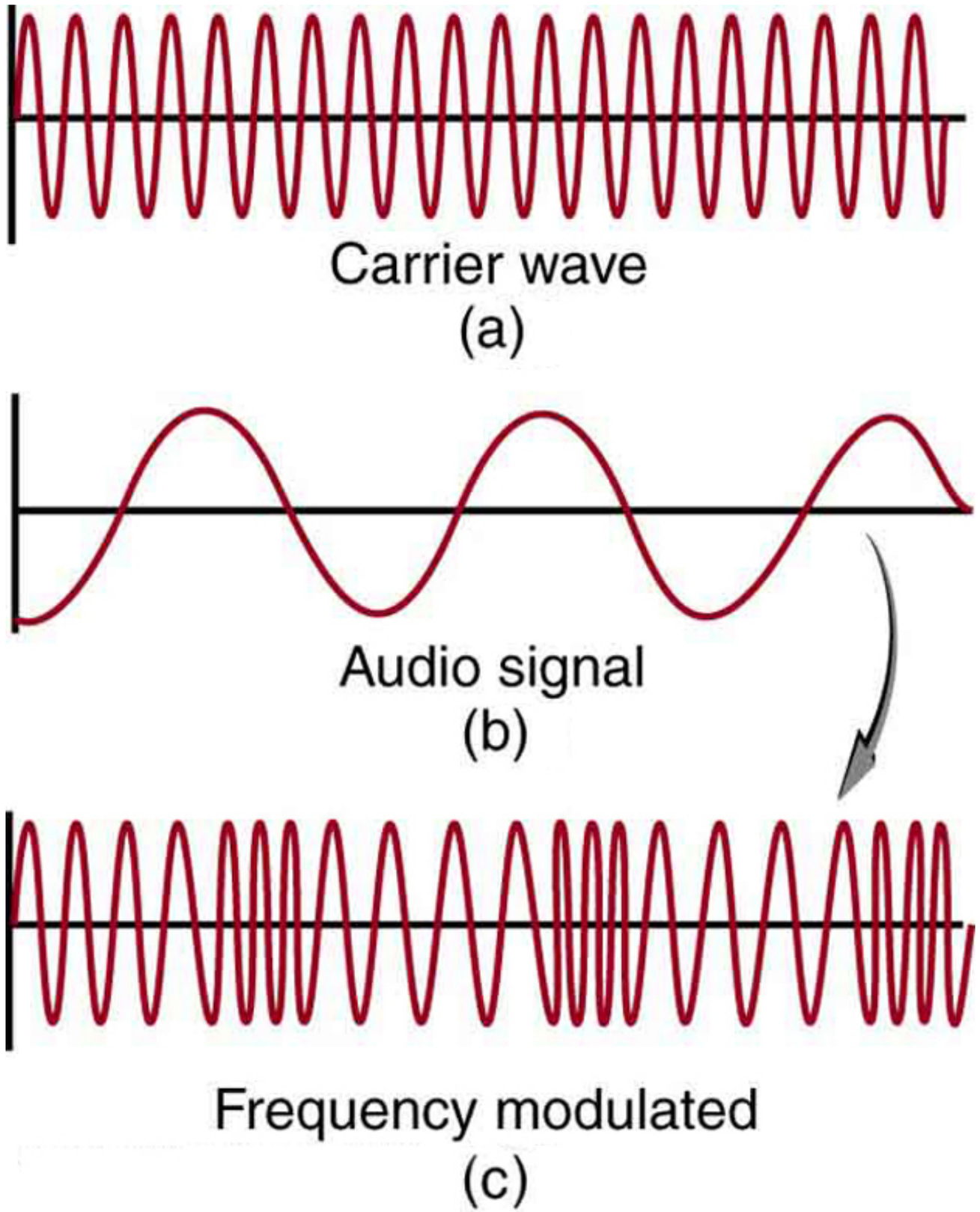


Audio

(b)

Amplitude modulated

(c)


Carrier wave
(a)
Audio signal
(b)
Frequency modulated
(c)

Type of EM wave	Production	Applications	Life sciences aspect	Issues
Radio & TV	Accelerating charges	Communications Remote controls	MRI	Requires controls for band use
Microwaves	Accelerating charges & thermal agitation	Communications Ovens Radar	Deep heating	Cell phone use
Infrared	Thermal agitations & electronic transitions	Thermal imaging Heating	Absorbed by atmosphere	Greenhouse effect
Visible light	Thermal agitations & electronic transitions	All pervasive	Photosynthesis Human vision	
Ultraviolet	Thermal agitations & electronic transitions	Sterilization Cancer control	Vitamin D production	Ozone depletion Cancer causing
X-rays	Inner electronic transitions and fast collisions	Medical Security	Medical diagnosis Cancer therapy	Cancer causing
Gamma rays	Nuclear decay	Nuclear medicineSecurity	Medical diagnosis Cancer therapy	Cancer causing Radiation damage

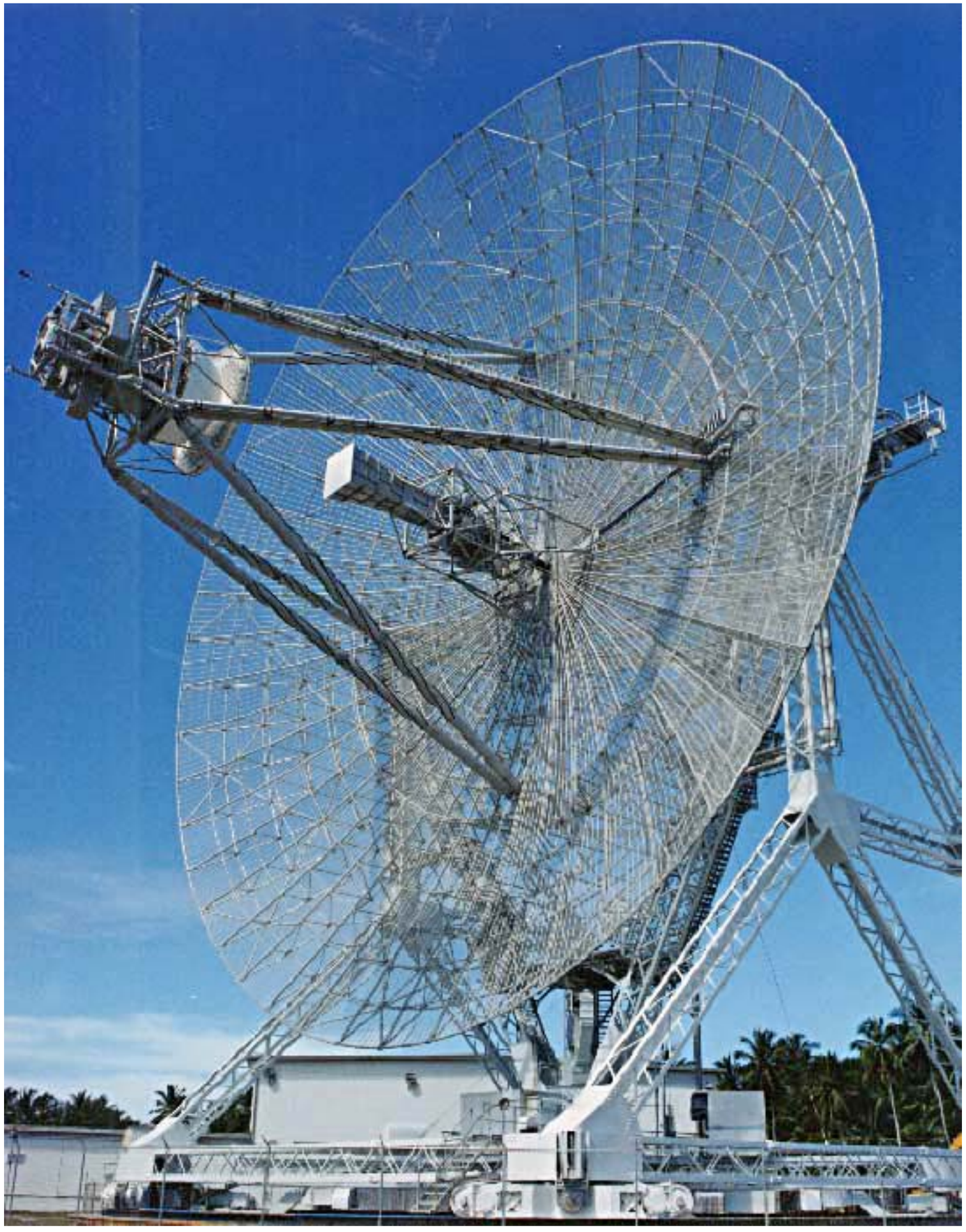
For any type of wave,

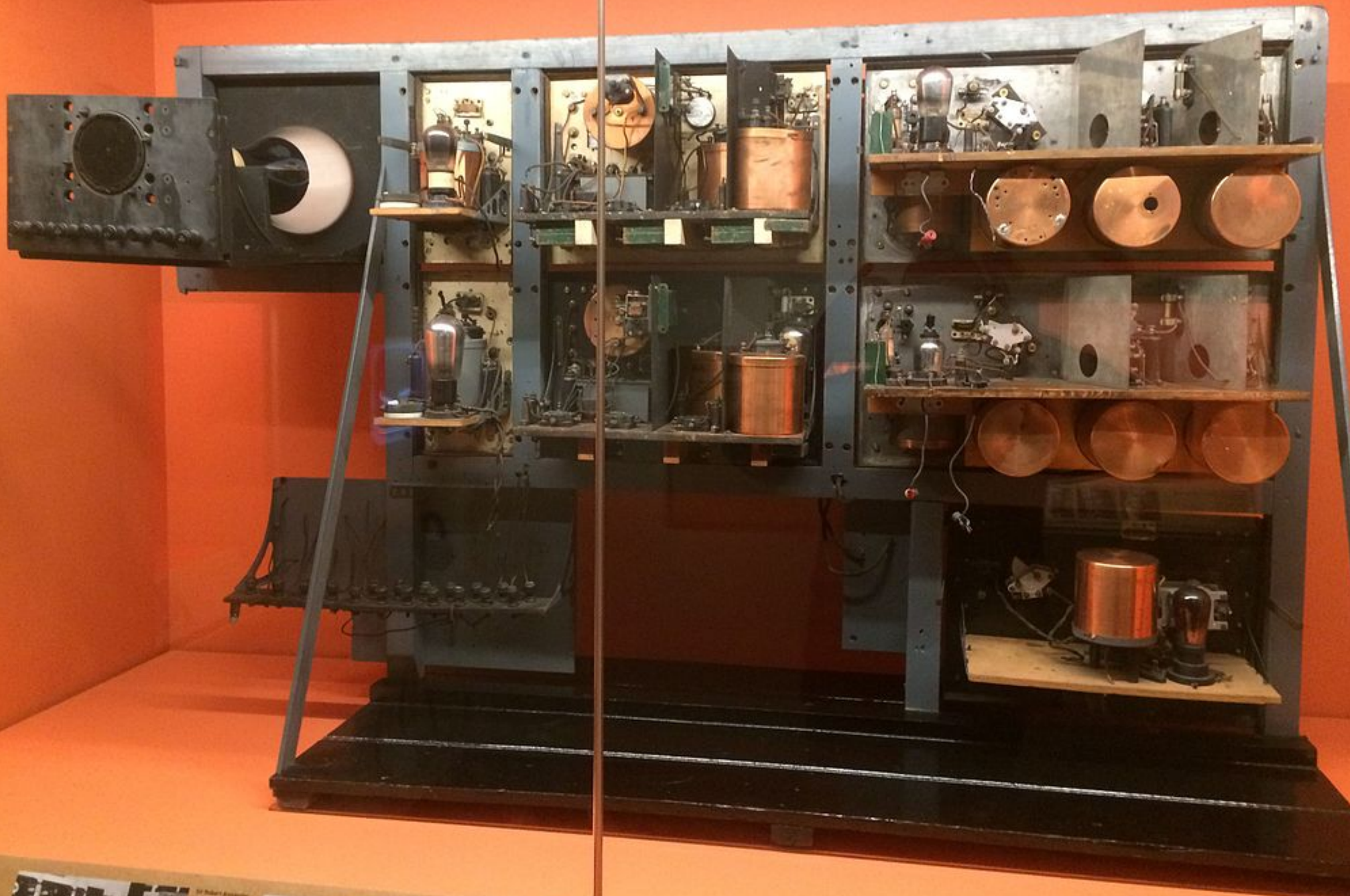
$$v = f\lambda$$

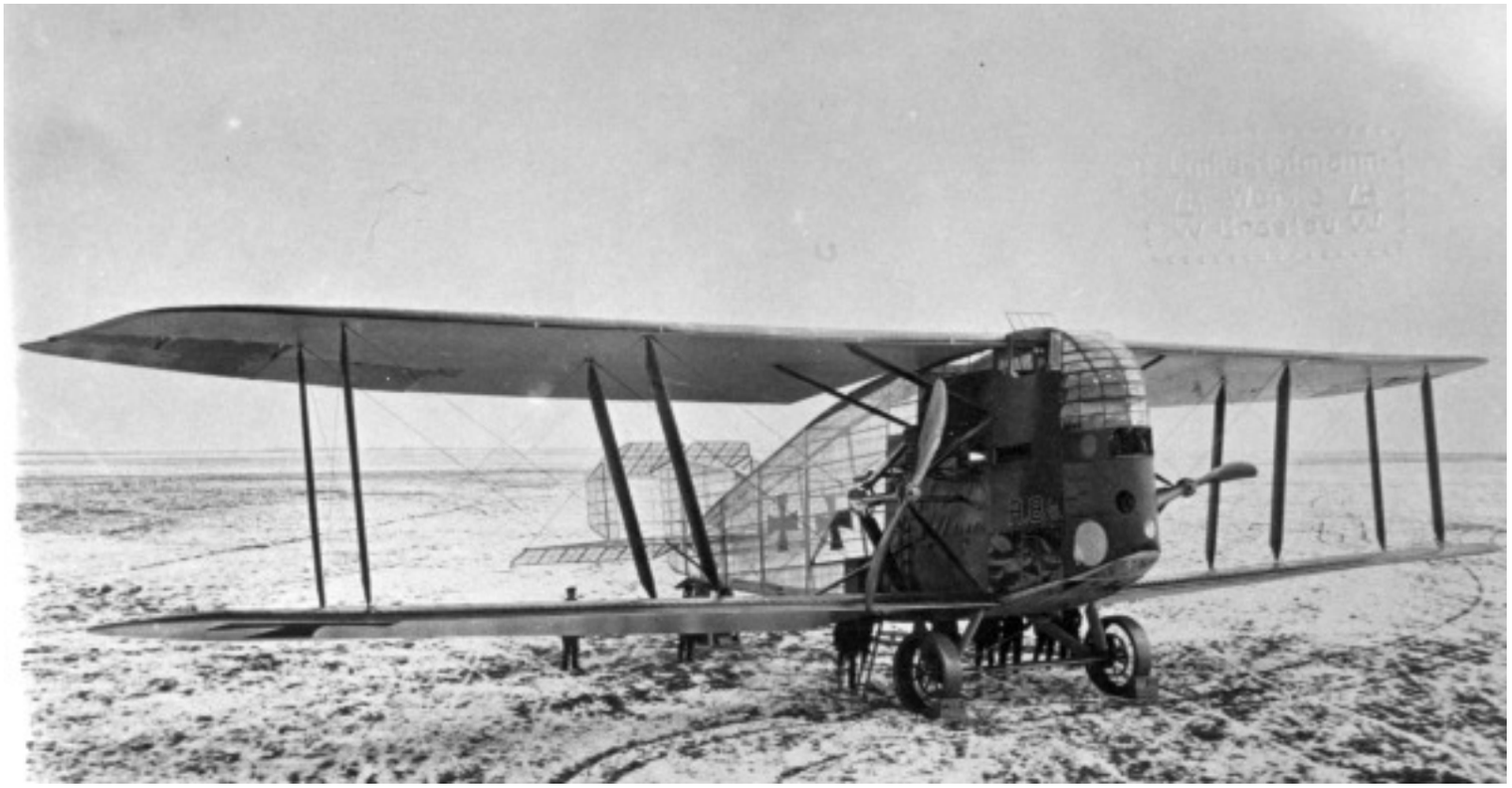
so for all EM waves,

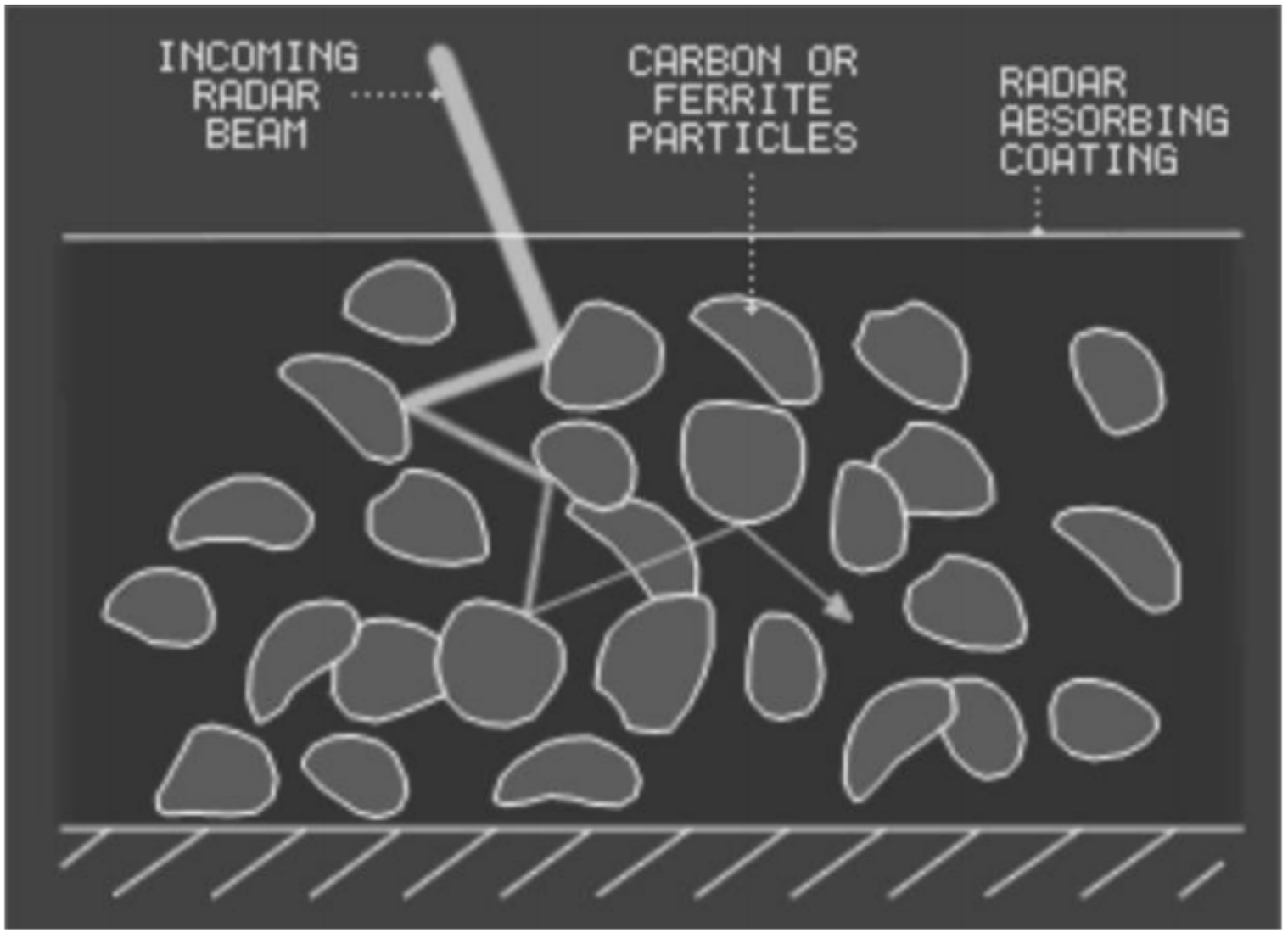
$$c = f\lambda$$

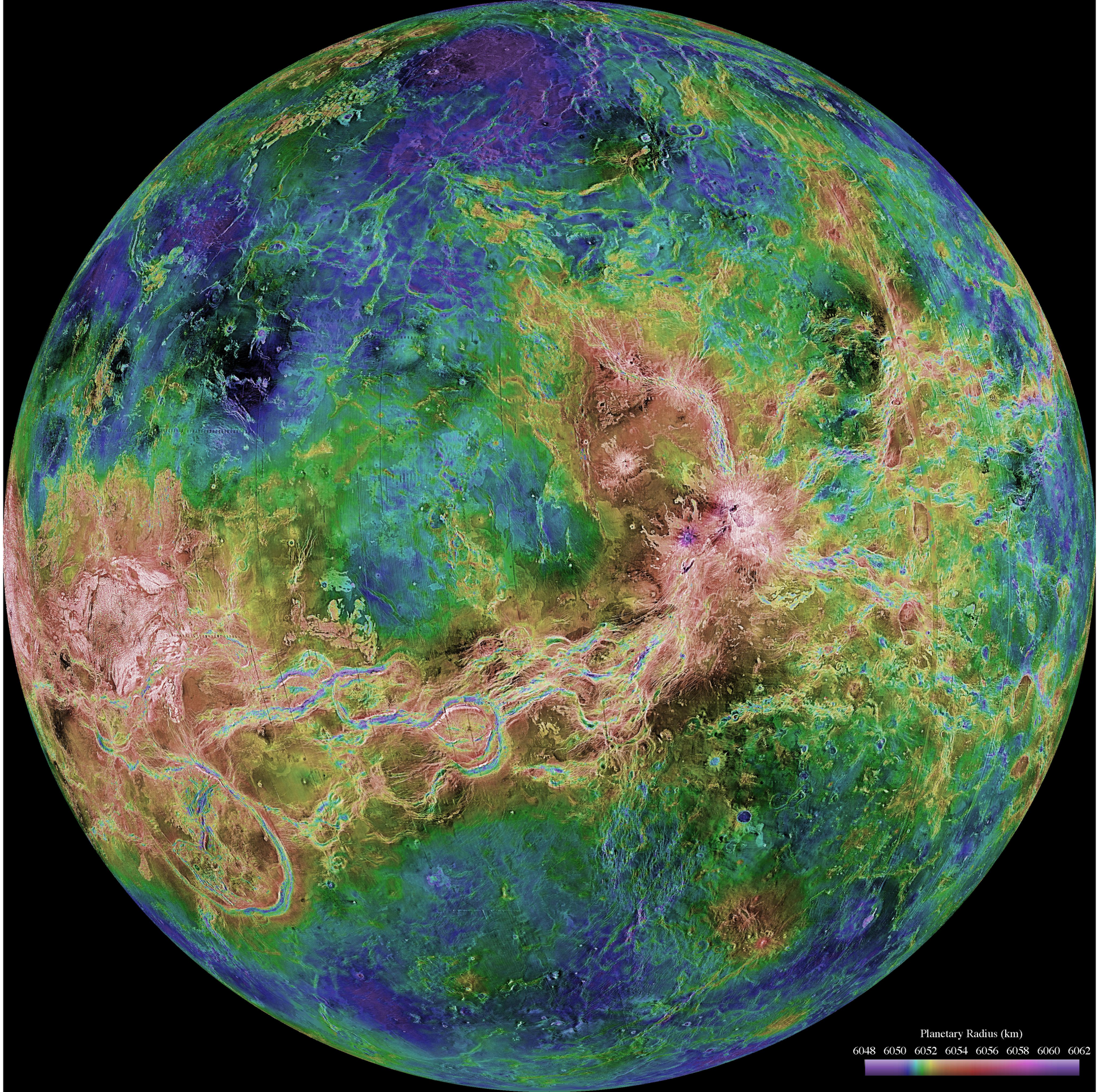
where the speed of light $c = 3.00 \times 10^8$ m/s.

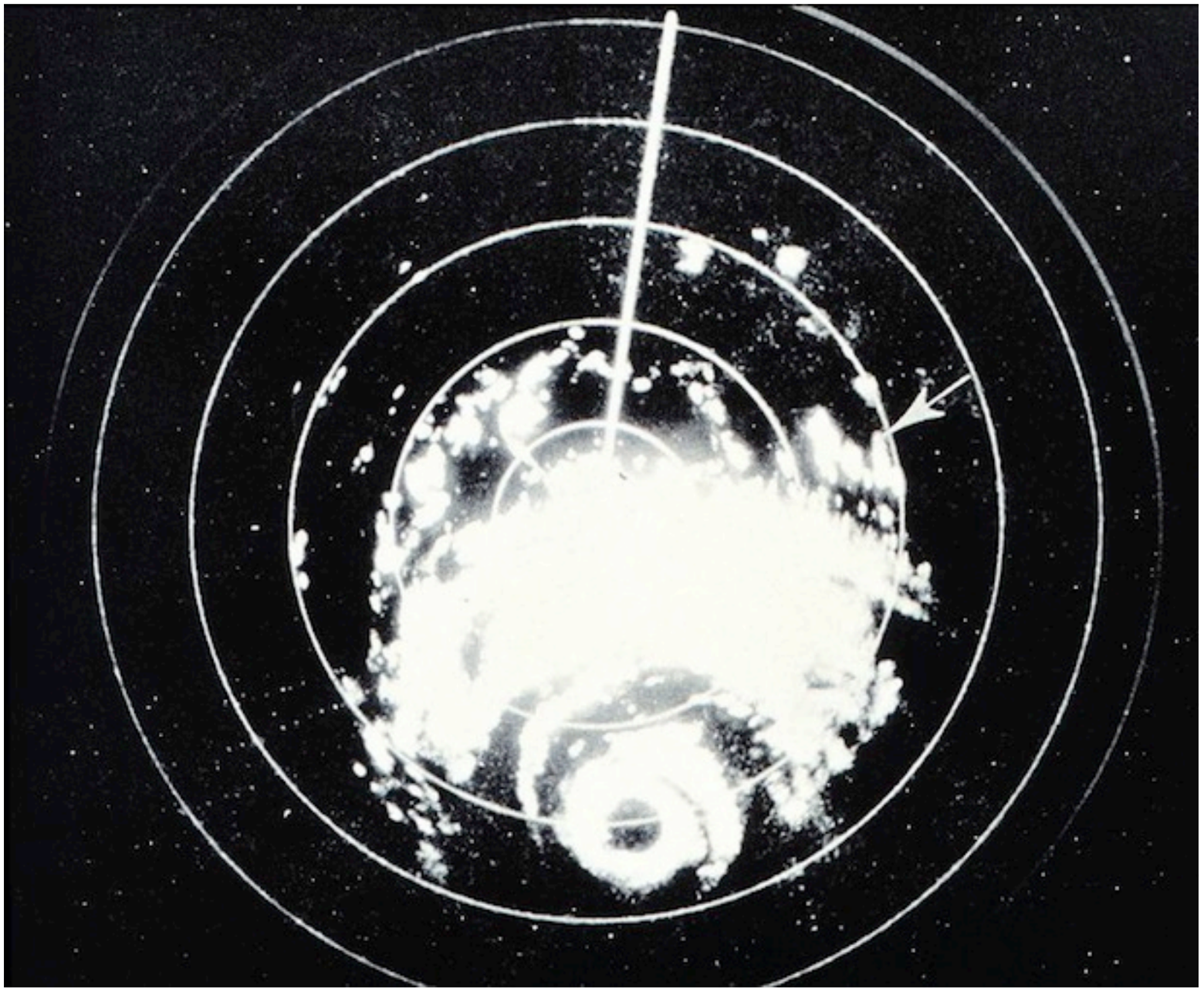


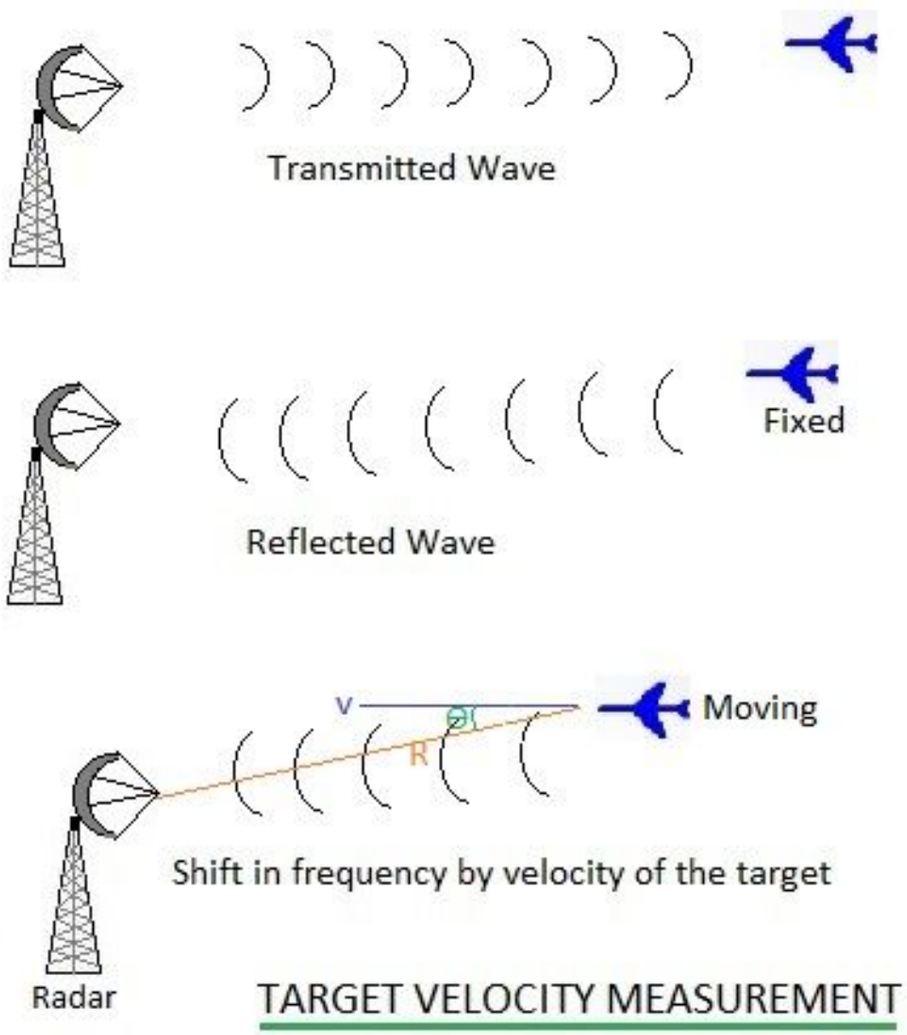


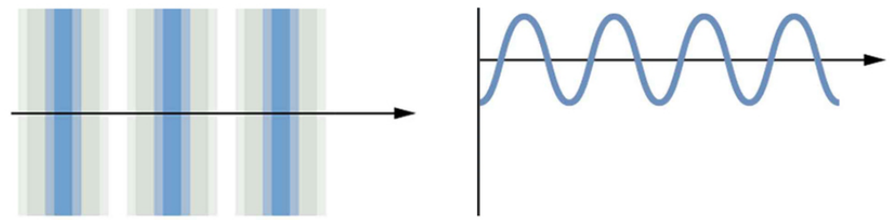


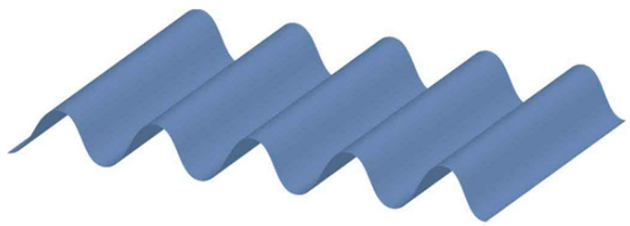

INCOMING
RADAR
BEAM
CARBON OR
FERRITE
PARTICLES
RADAR
ABSORBING
COATING


Planetary Radius (km)
6048 6050 6052 6054 6056 6058 6060 6062

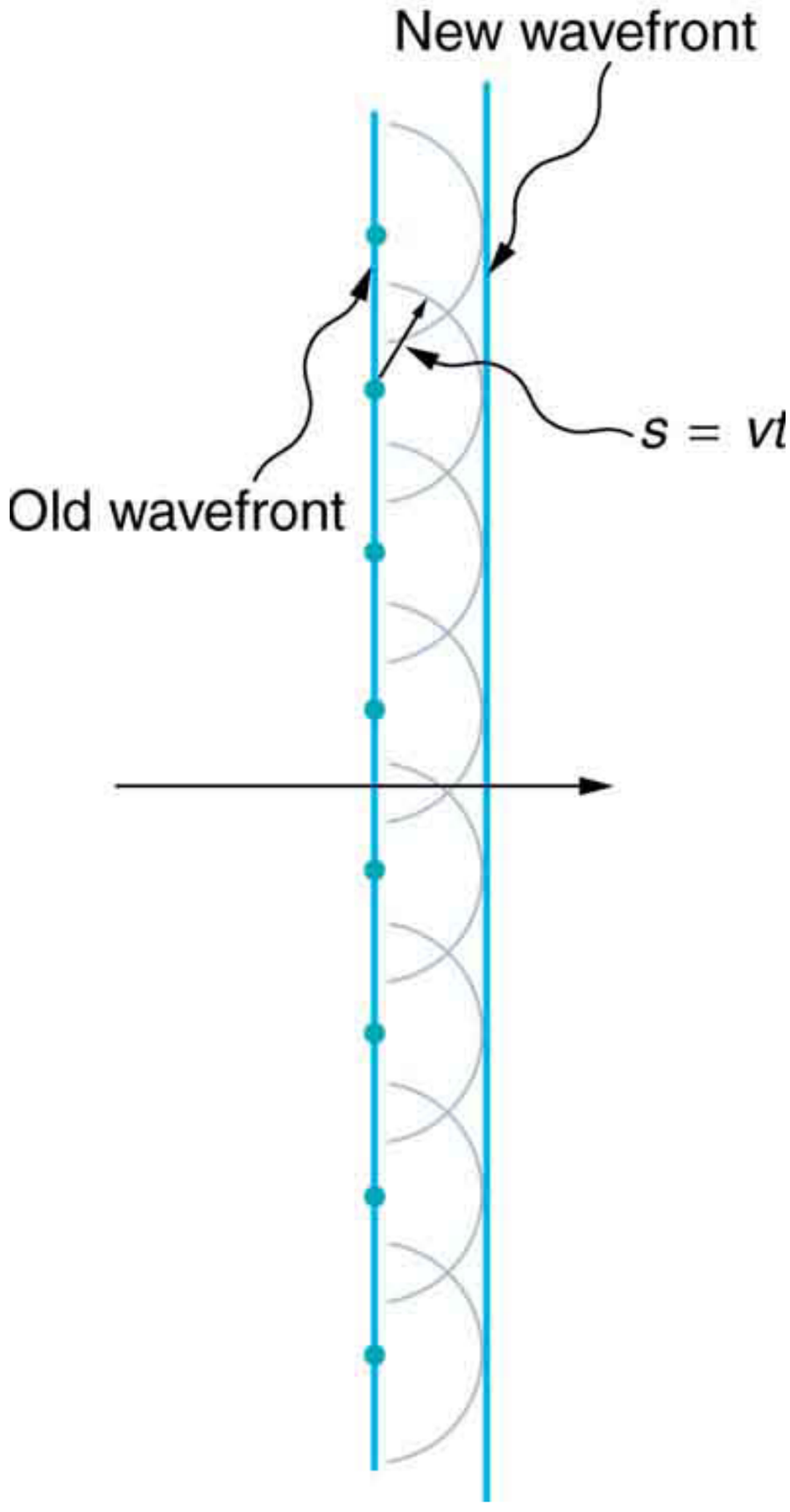


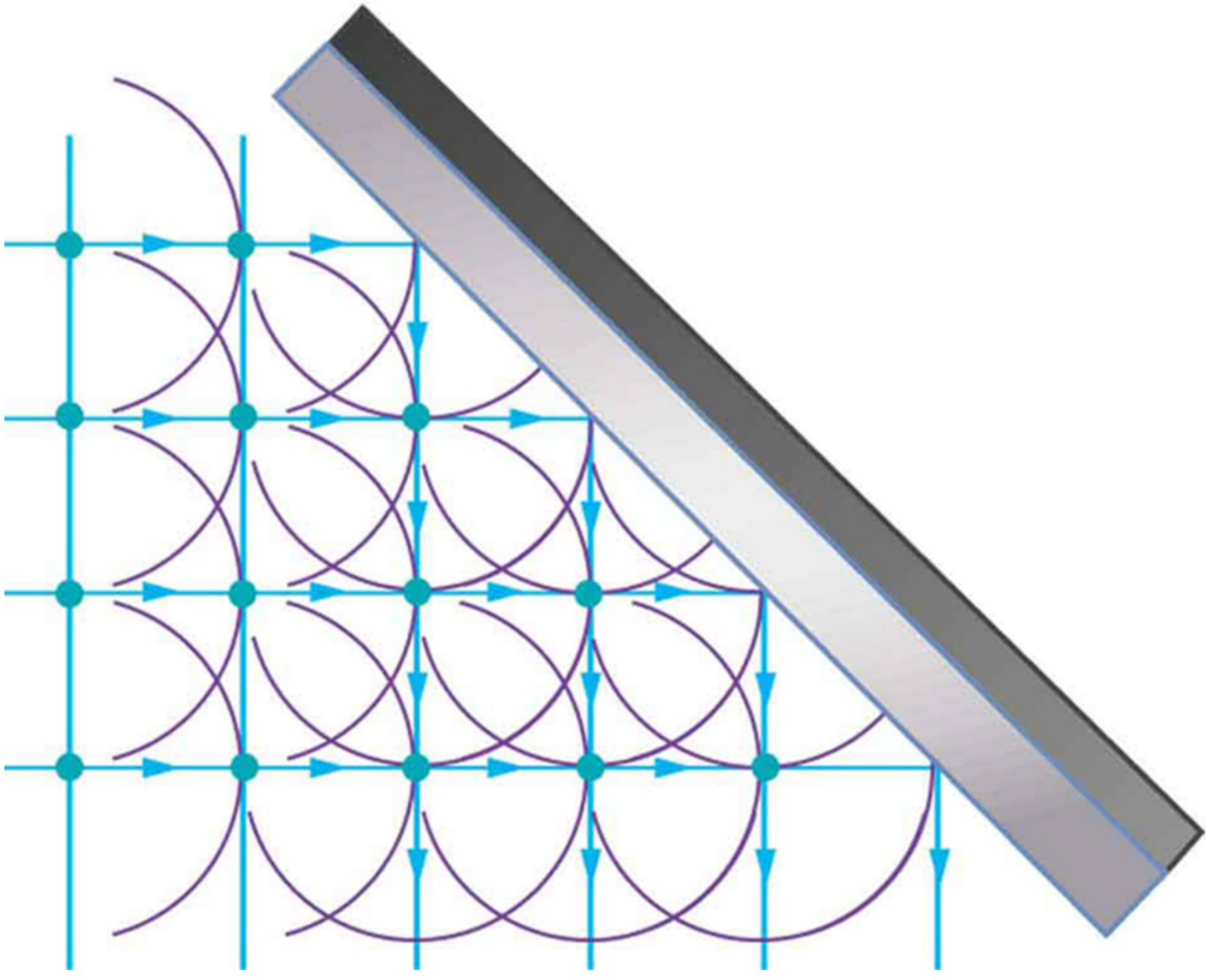

Transmitted Wave
Fixed
Reflected Wave
V
R
Moving
Shift in frequency by velocity of the target
Radar
TARGET VELOCITY MEASUREMENT

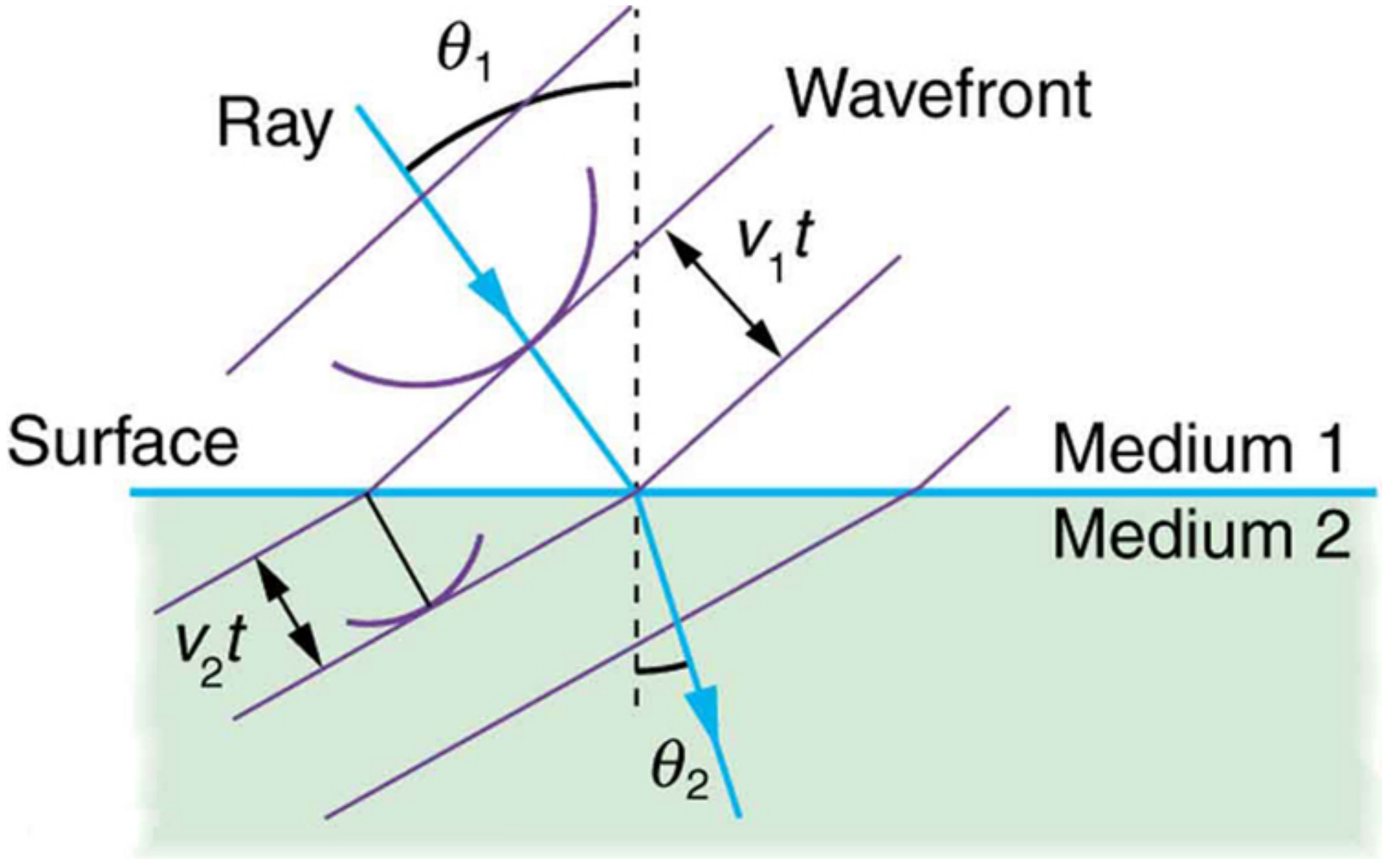


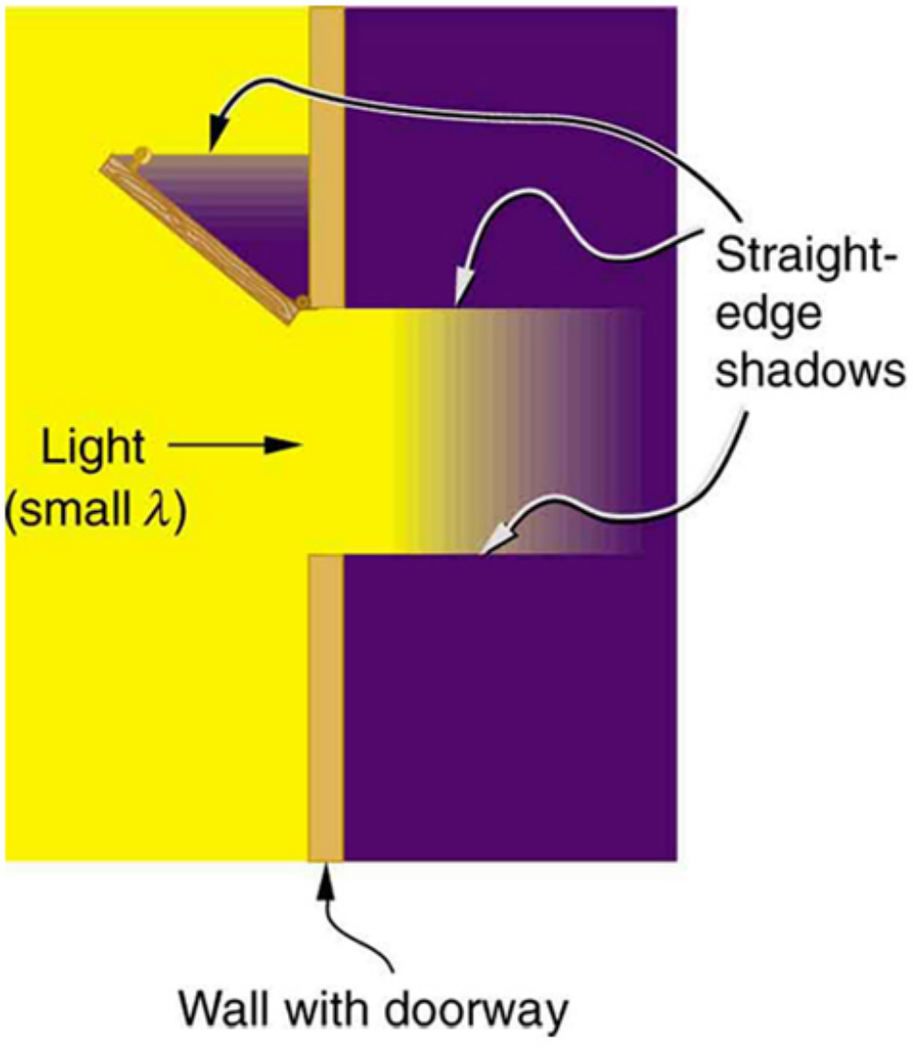


Overall view

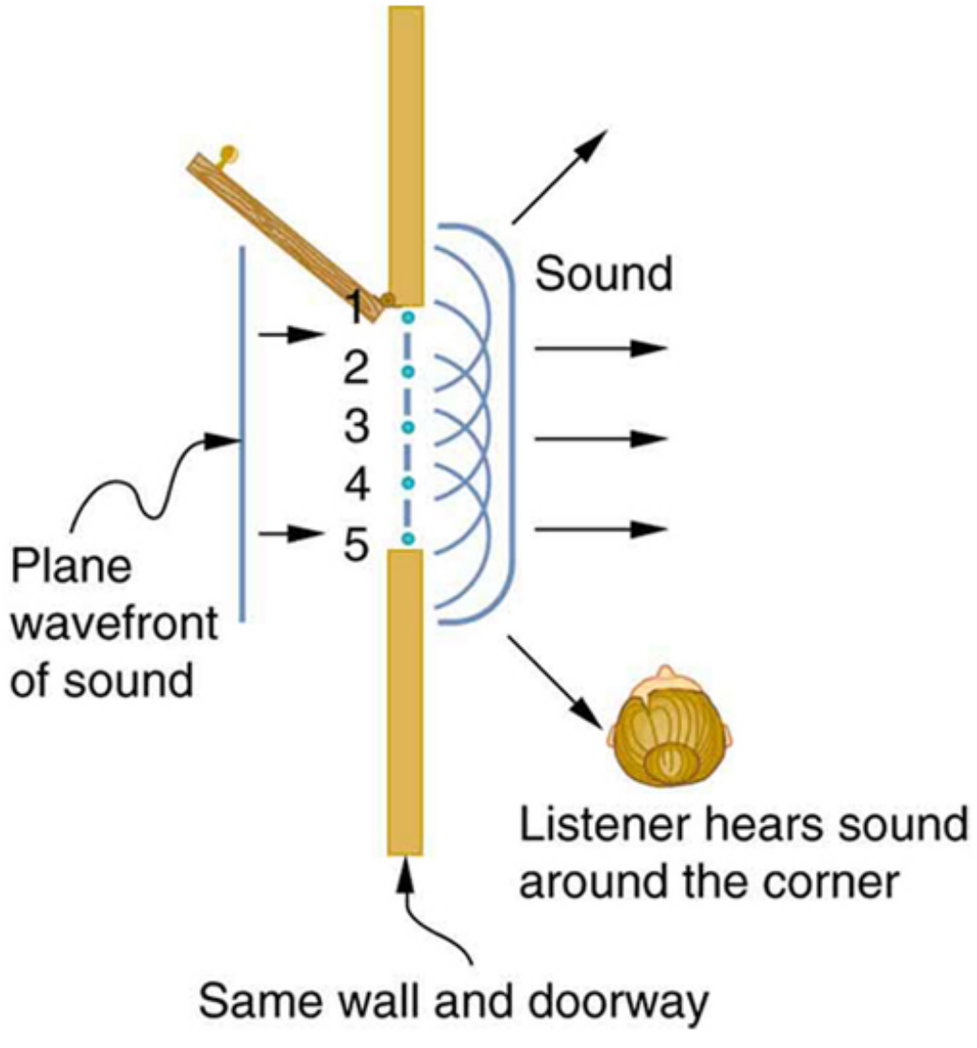

New wavefront
$s = vt$
Old wavefront



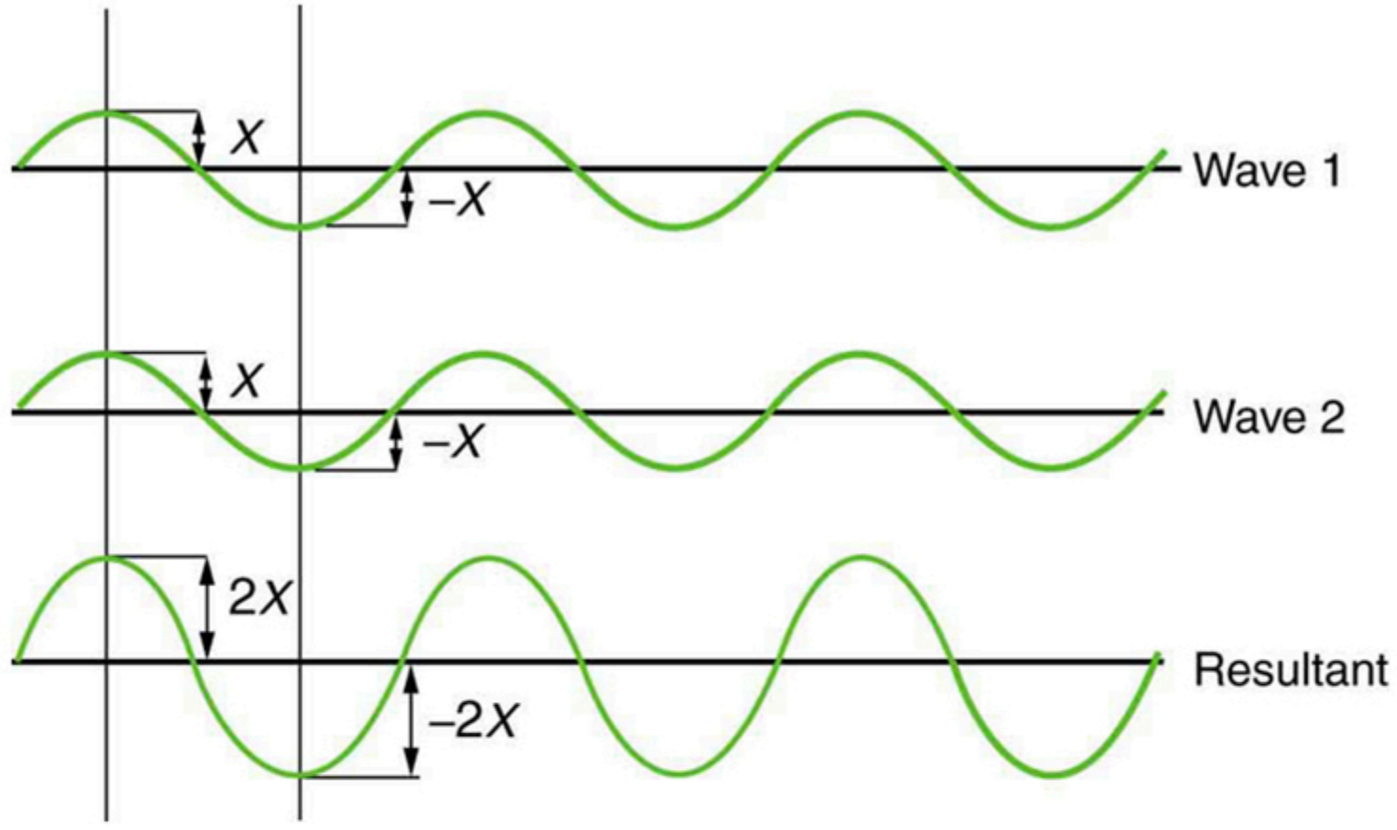

θ_1
Ray
Wavefront
$v_1 t$
Surface
Medium 1
Medium 2
$v_2 t$
θ_2


Straight-
edge
shadows
Light
(small λ)
Wall with doorway

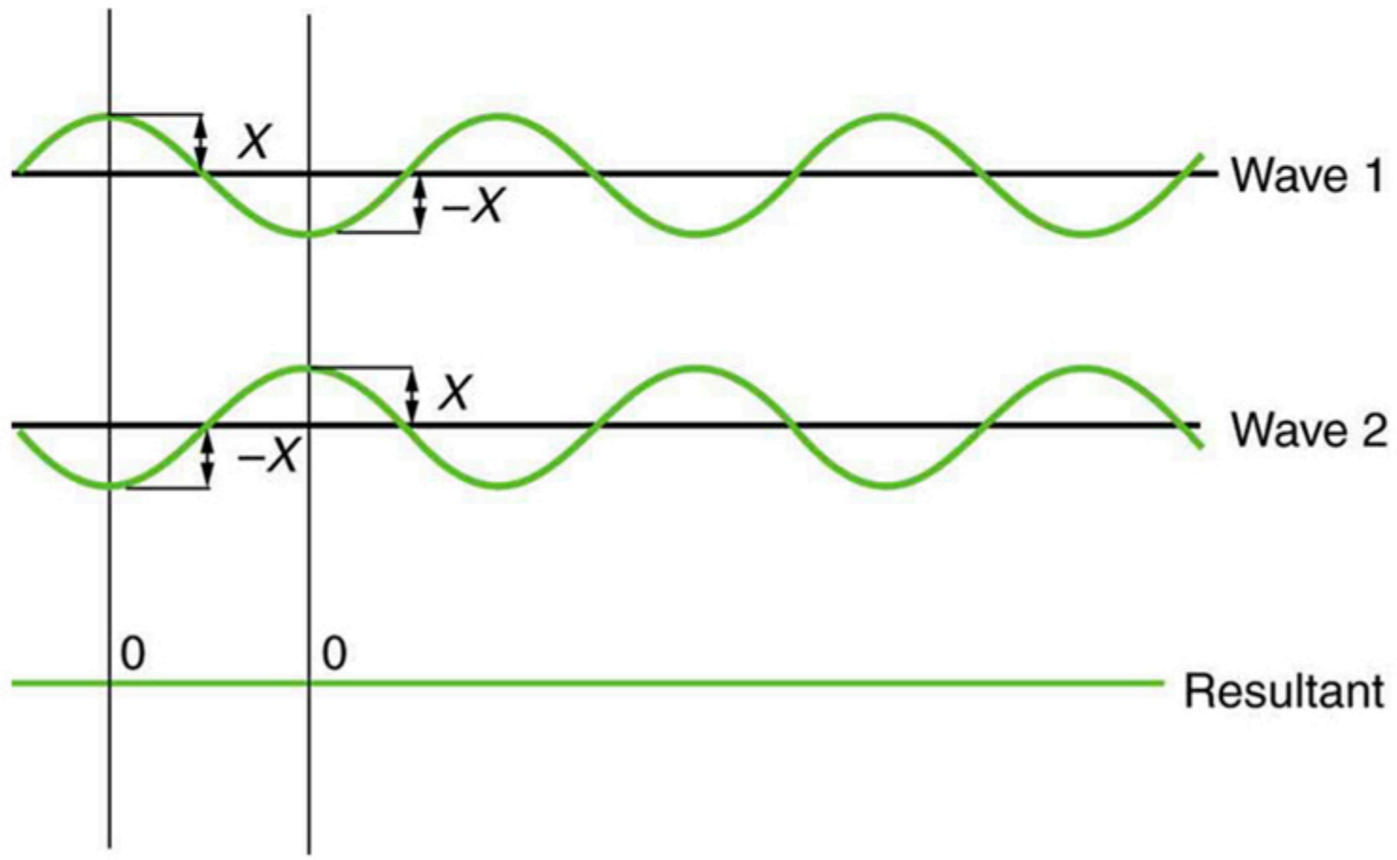
(a)


Sound
1
2
3
4
5
Plane
wavefront
of sound
Listener hears sound
around the corner
Same wall and doorway

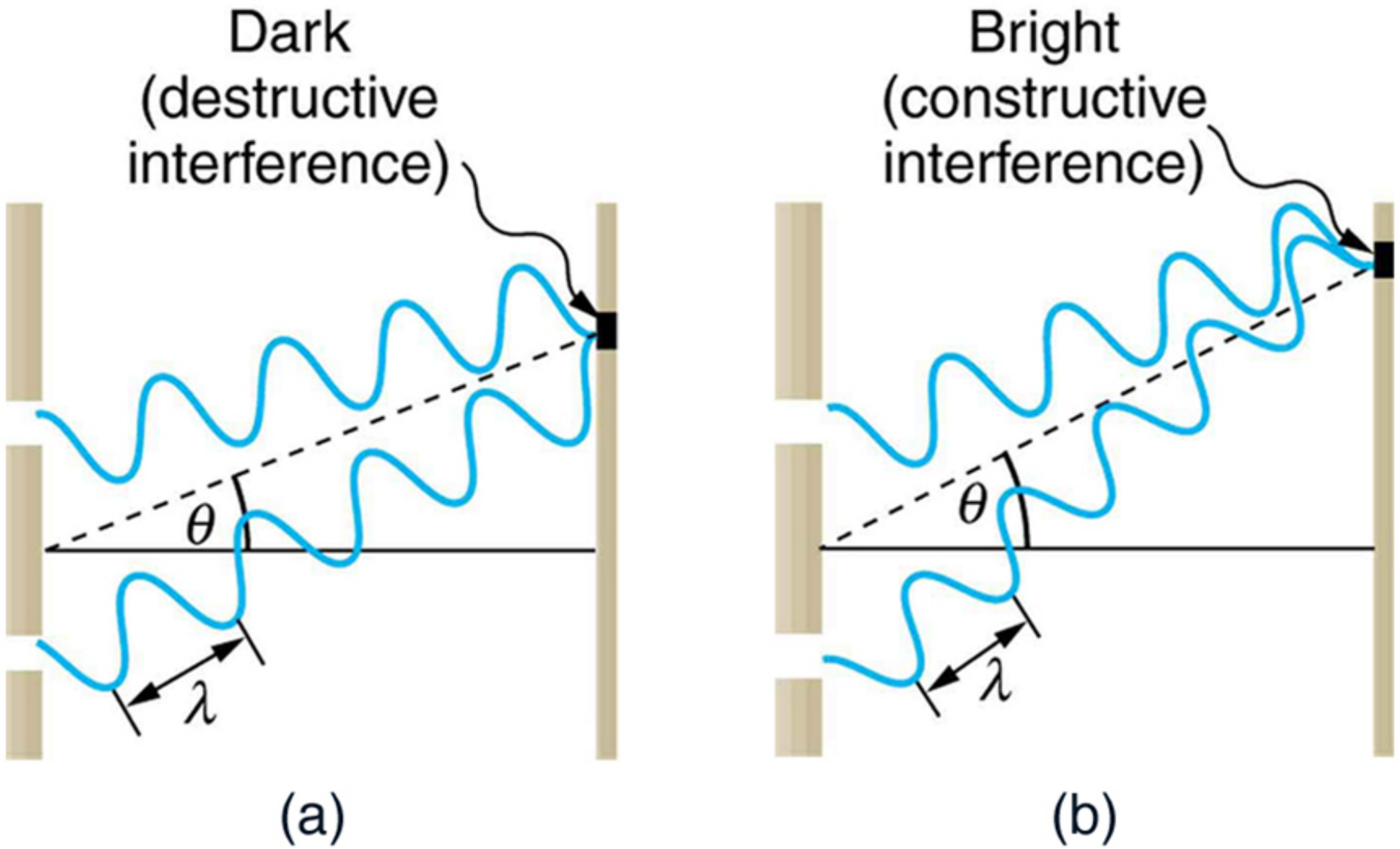
(b)


X
−X
Wave 1
X
−X
Wave 2
2X
−2X
Resultant

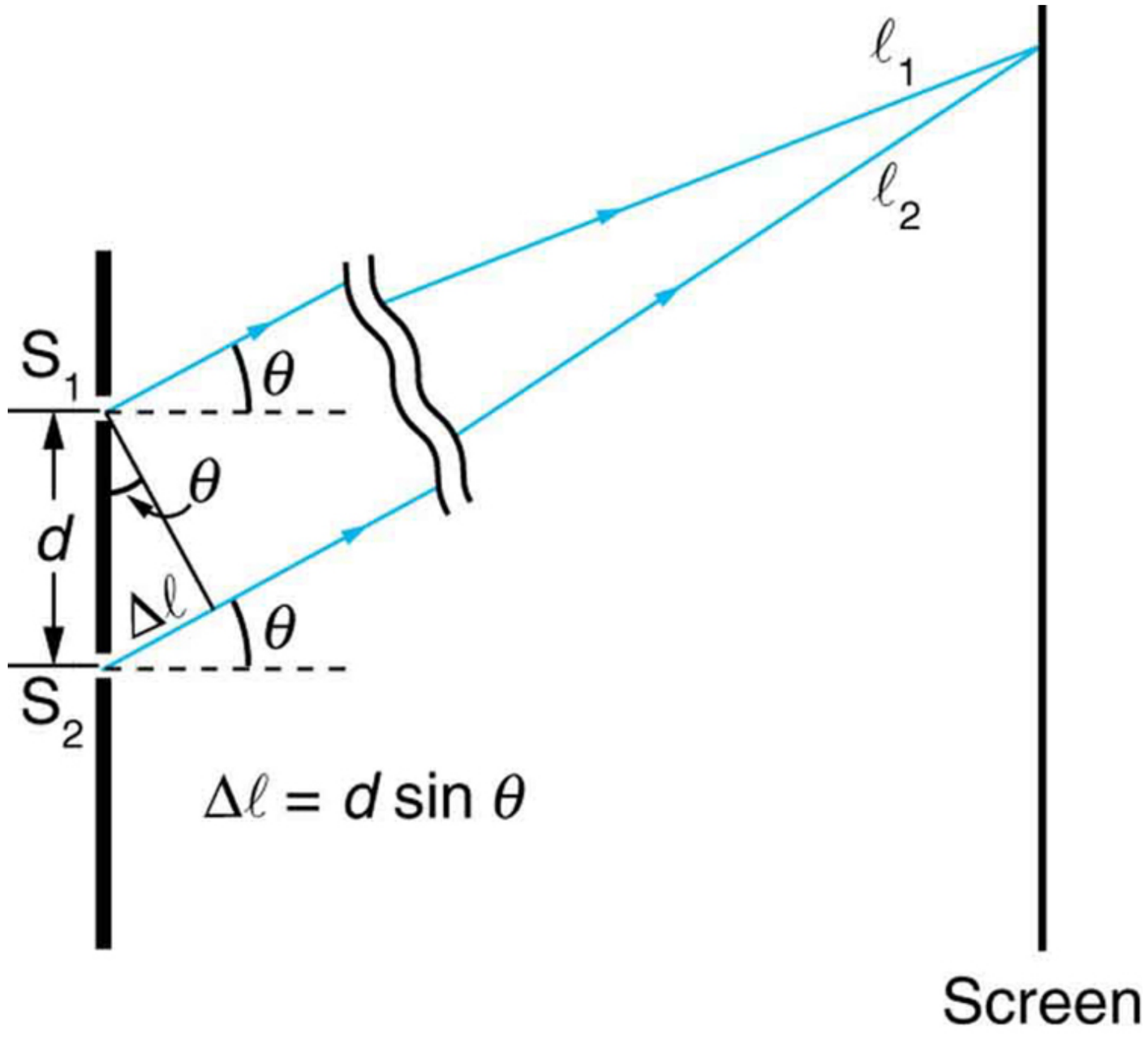
(a)

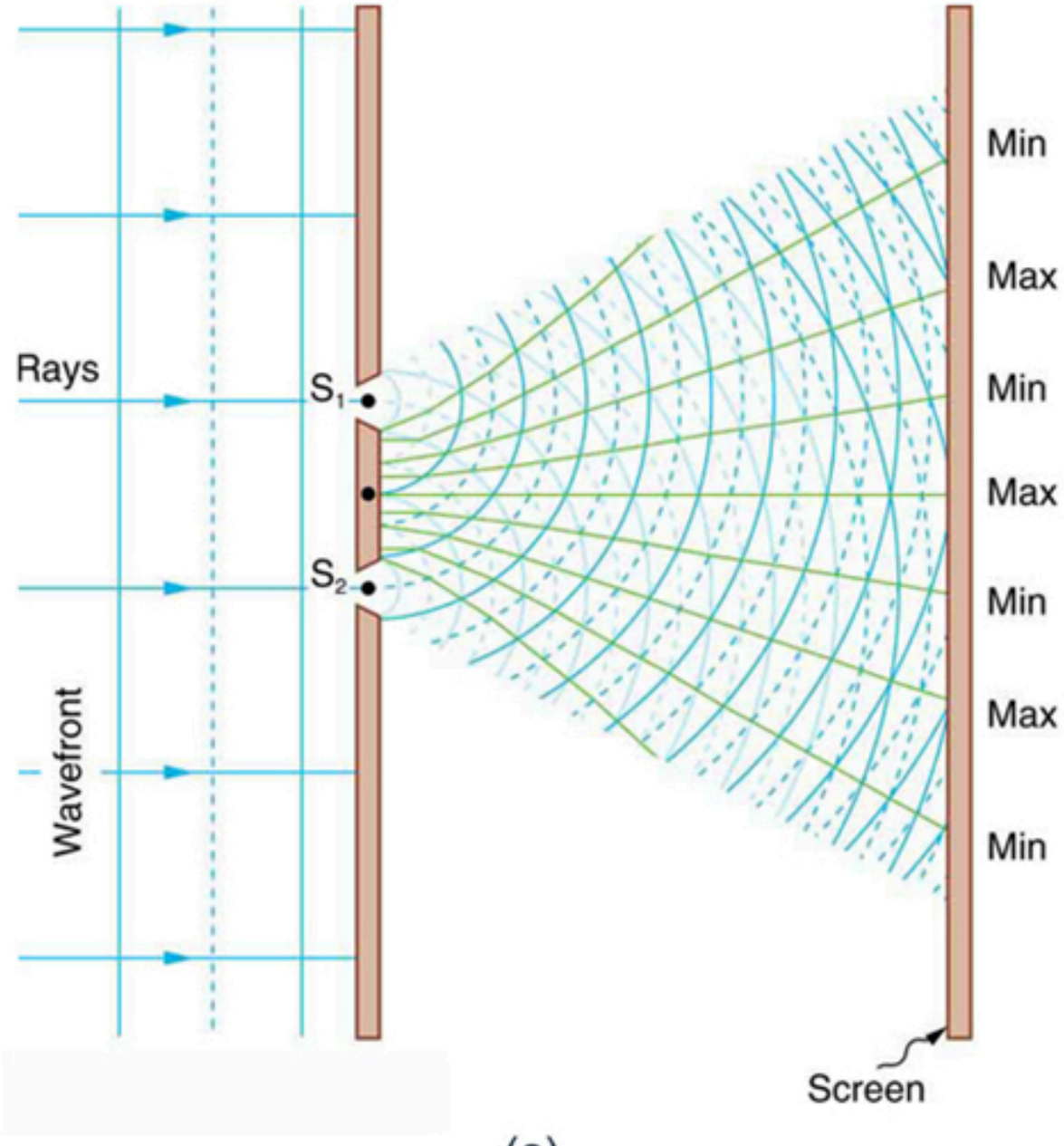

X
−X
Wave 1
X
−X
Wave 2
0
0
Resultant

(b)

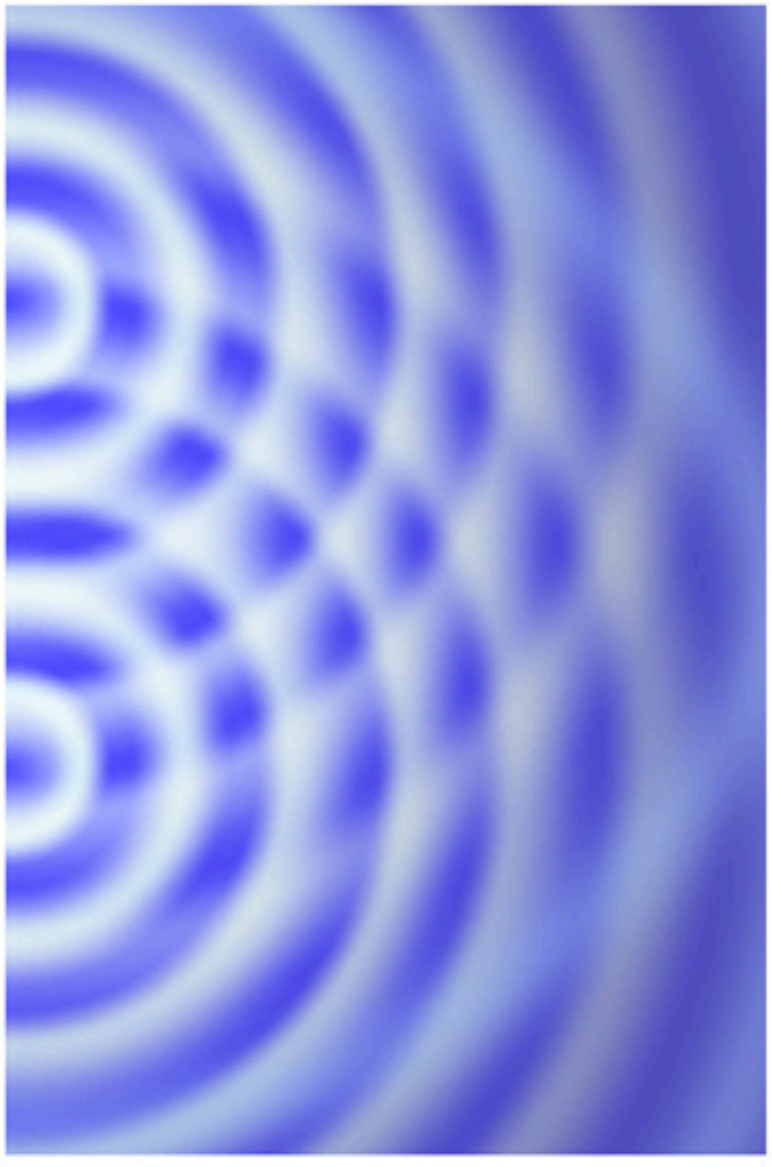

Dark
(destructive
interference)
θ
λ
Bright
(constructive
interference)
θ
λ

(a) (b)


ℓ_1
ℓ_2
S_1
θ
θ
d
$\Delta\ell$
θ
S_2
$\Delta\ell = d \sin \theta$
Screen



(a)



(b)

(c)

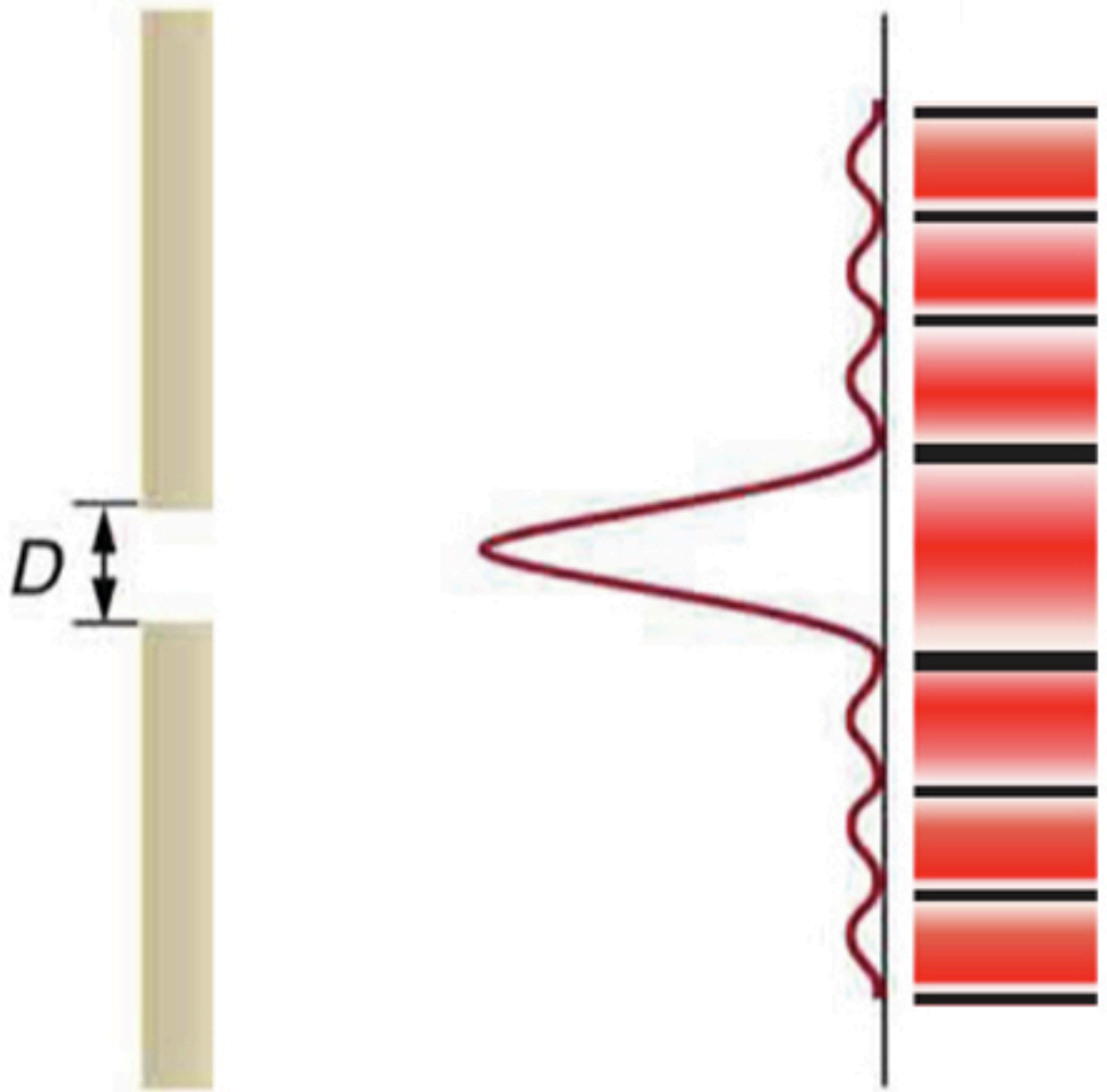
Will we observe a diffraction pattern from a single slit?

A. Light of different frequencies passing through the slit will interfere constructively or destructively depending on the angle.

B. Different wavelengths of light passing through the slit will interfere constructively or destructively depending on the angle.

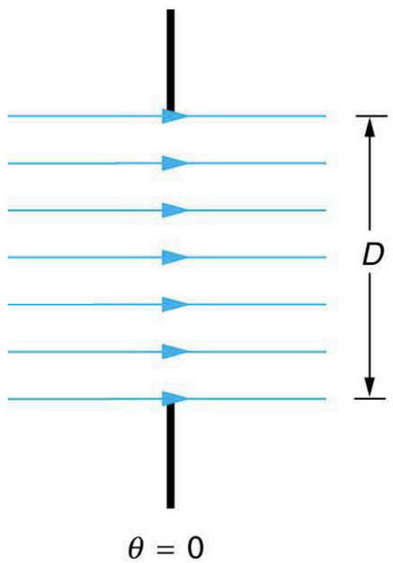
C. Light coming from different parts of the same slit will interfere constructively or destructively.

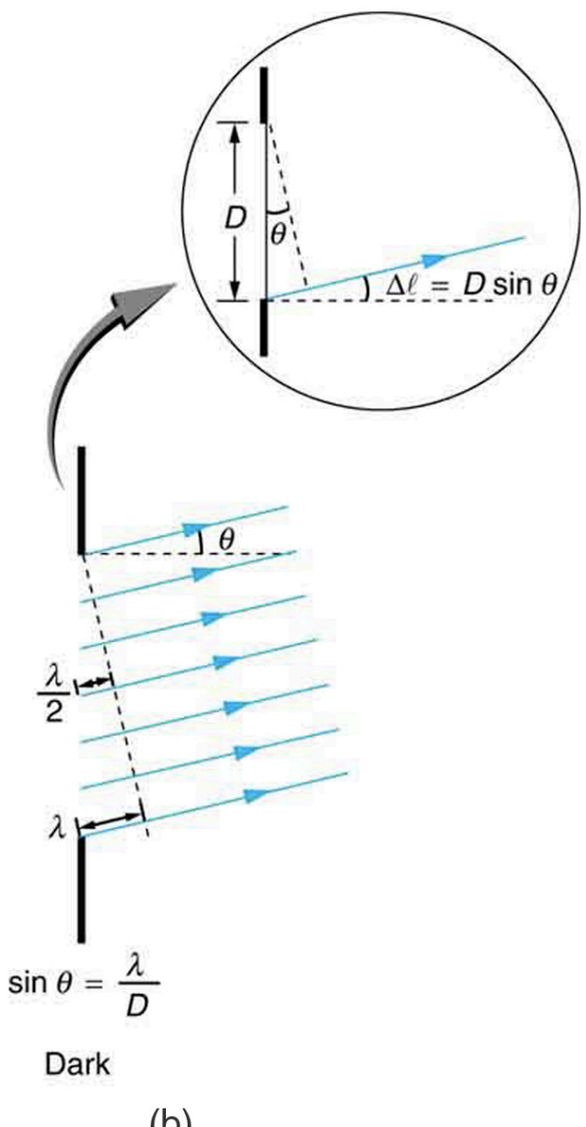
D. No diffraction pattern should be seen.

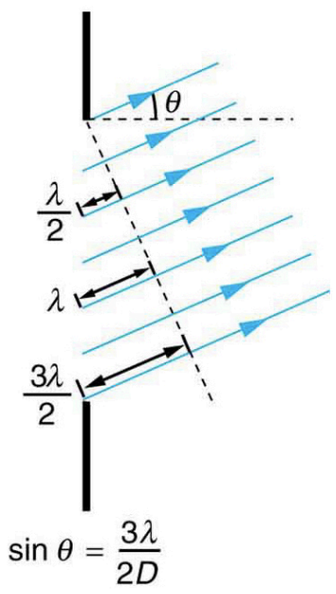


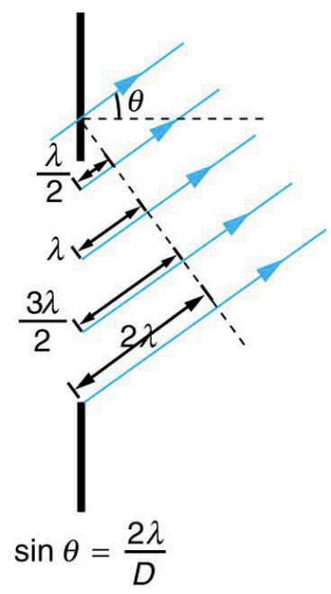
(a)

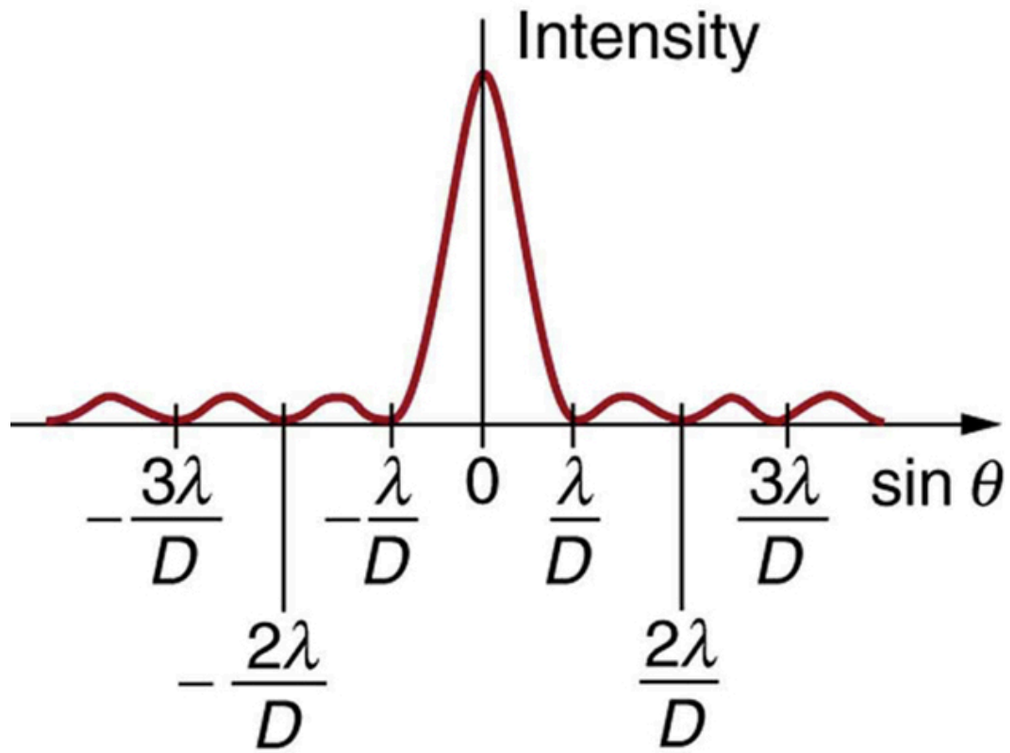
(b)











Destructive interference for single slit:

$$D \sin\theta = m\lambda$$

for m = -1, +1, -2, +2, ...