Modern Physics, Session 3: 3rd Sept 2022, Saturday, 6.00 – 7.15 pm

Q 1. An electromagnetic wave in vacuum: $E = E_0 \sin(kx - \omega t)$. Which is independent of wavelength?

A). k
B). ω
C). k/ω
D). kω

k = no. of waves per unit m

$k = 2\pi/\lambda$

$\omega = 2\pi f$

$\omega = 2\pi \frac{c}{\lambda}$

$c = f\lambda$

$v = f\,\text{lambda}$ Mnemonic

$k/\omega = \frac{2\pi}{\lambda} \cdot 2\pi f = \frac{2\pi}{\lambda} \cdot \frac{\lambda}{2\pi c} = 1/c$

Today's subtopics on dual nature of light:

1). Recap
2). Time delay & frequency perspectives
3). Photon's Birthday
4). Photon vs material particles
5). Photoelectric effect setup

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Q 1. An electromagnetic wave in vacuum: $E = E_0 \sin(kx - \omega t)$. Which is independent of wavelength?

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B). ω
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D). $k\omega$

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Q 2. A free electron is placed in the path of a plane electromagnetic wave. The electron will start moving

A). along the electric field
B). along the magnetic field
C). along wave propagation direction
D). in a plane containing magnetic field & direction of propagation

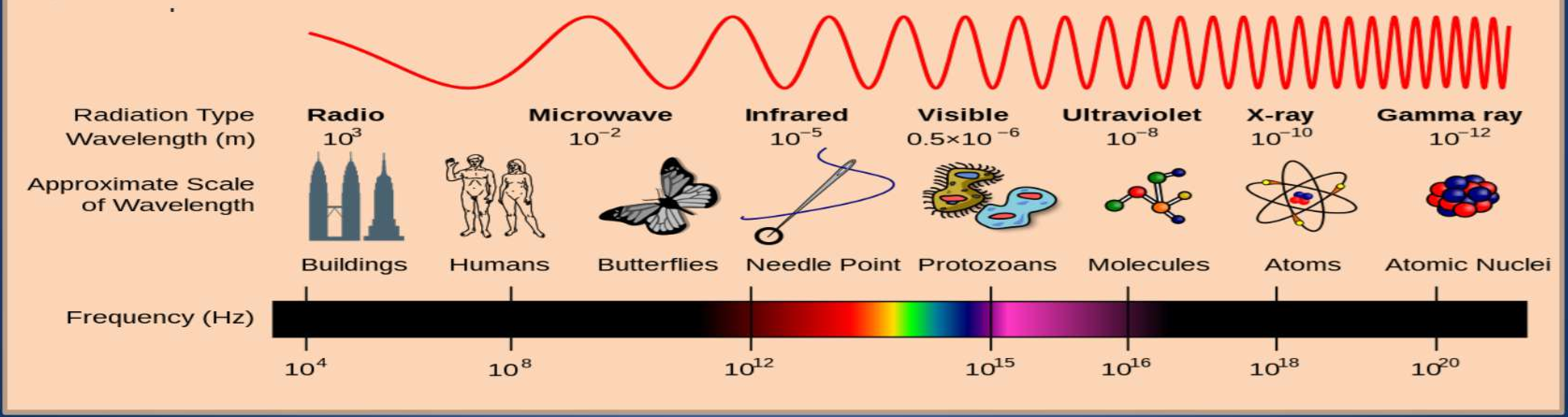
Q 3). Speed of EM waves is the same

A). for all wavelengths
B). for all intensities
C). in all inertial frame
D). In all media

Maxwell derived speed of EM wave, $v = E_0/B_0$

Constant. $v = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 3\times10^{8} = 299,792,458\ m/s$

$\mu_0 \rightarrow 4\pi\times10^{-7}$



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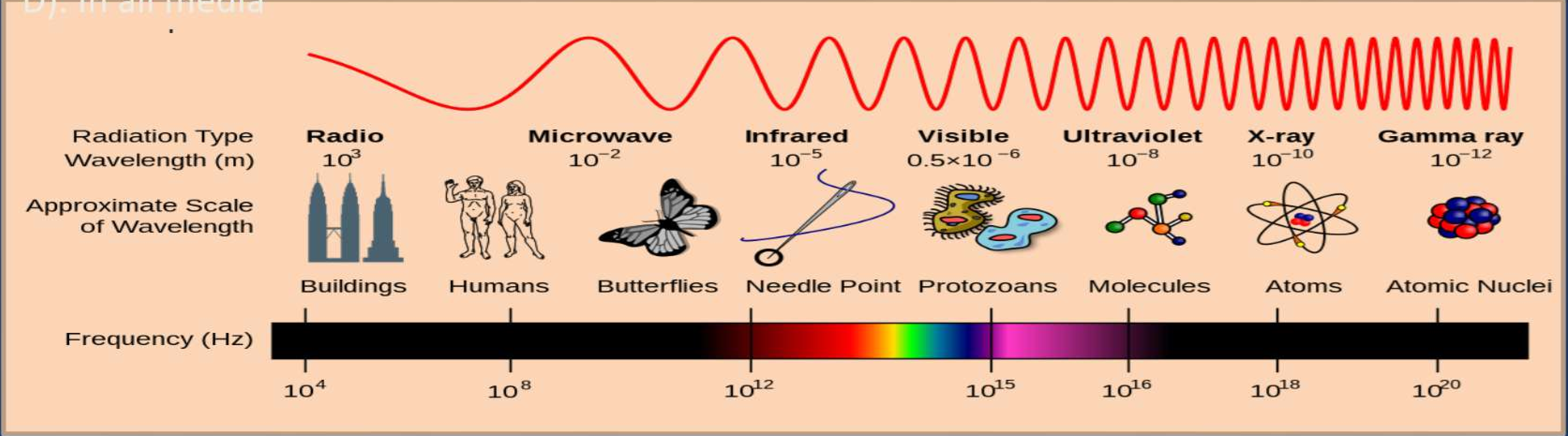
No mechanics experiment can tell if the FoR is moving or at rest.



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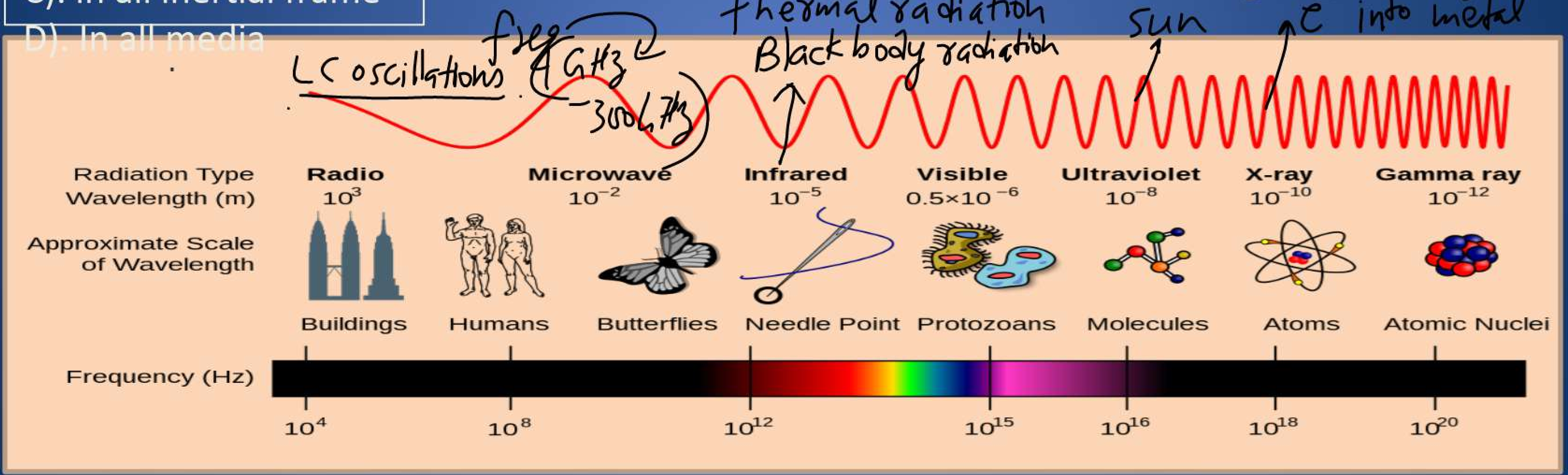
Maxwell said that an EM wave is generated whenever a charged particle accelerates.



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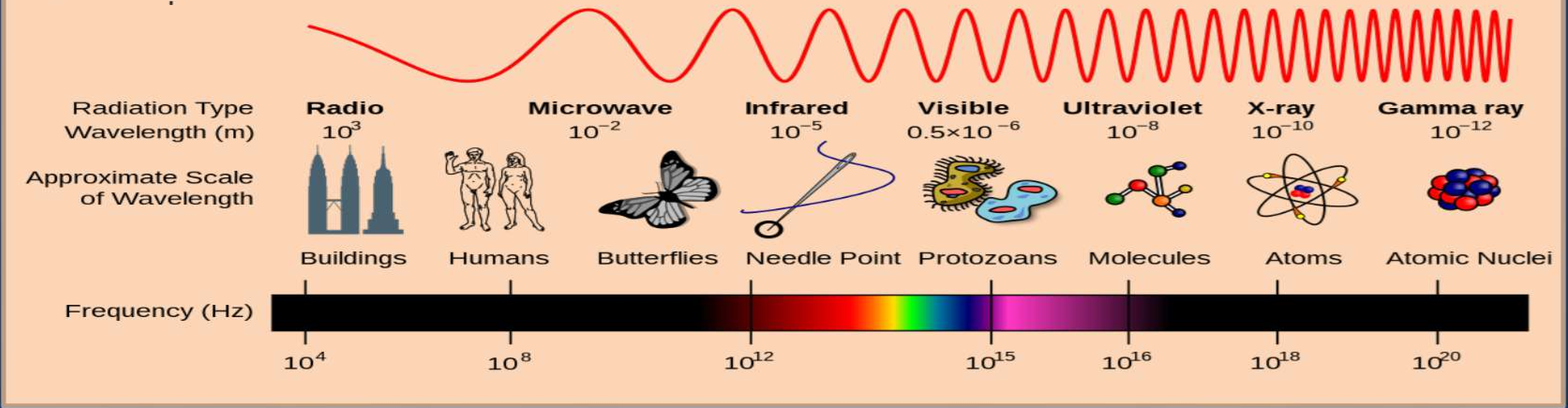
$E = E_0 \sin(\omega t - kx)$

1D wave

Q 4). Which have zero average value in a plane EM wave

A). Electric Field
B). Magnetic Field
C). Electric Energy
D). Magnetic Energy



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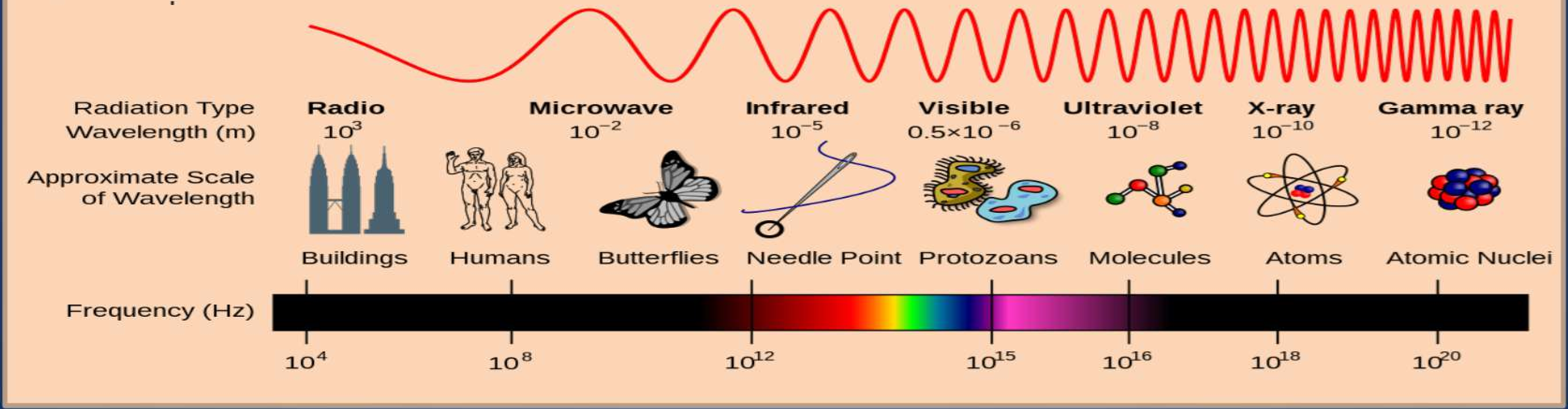

Q 5). Intensity of sound wave is proportional to

A). $(\text{amplitude})^2$ ✓
B). $(\text{frequency})^2$ → $\propto \omega$ ($2\pi f$)
C). density
D). wave number

$$I = \frac{1}{2}\rho v \omega^2 S_0^2$$

$$= \frac{P_0^2}{2\rho v}$$

$$= \frac{1}{2} P_0 \omega S_0 \rightarrow \boxed{\omega}$$

Q 5). Intensity of sound wave is proportional to

A). $(\text{amplitude})^2$
B). $(\text{frequency})^2$
C). density
D). wave number

Q 6). Intensity of light/EM wave is proportional to

A). $(\text{amplitude})^2$
B). $(\text{frequency})^2$
C). density
D). wave number

Today's session starts now…

Sh-> Why is the ejection of electrons from the metal surface, a threat to wave nature of light?

G -> Light is an EM wave was just confirmed. And then

G-> How can you produce light?

A). Heating a filament
B). Friction
C). Moving electrons
D). Accelerating electrons

Hertz, Hallwachs & Lenard in 1887-88, observed the spark in an attempt to produce EM wave by accelerating the electrons produced.

G-> The spark is barely visible with enormous visible light but became vigorous upon small UV light exposure.

G-> Three perspectives to the threat to wave nature.

1). Intensity perspective
2). Time delay perspective
3). Frequency perspective

Today's session starts now…

Sh-> Why is the ejection of electrons from the metal surface, a threat to wave nature of light?

Intensity Perspective → $I = \frac{1}{2}\epsilon_0 E_0^2 c$

Total energy incident ← $U = IAt$

ϕ, wave f^n

Force on a e^- → eE_0

(e^- free in the metal)

G-> Three perspectives to the threat to wave nature.

1). Intensity perspective

2). Time delay perspective

3). Frequency perspective

Sh -> What is Time Delay Perspective ?

G-> It is the minimum time that light wave would take to cause emission

Solve the following:

$\bar{e}$ should take some time to come out of metal surface.

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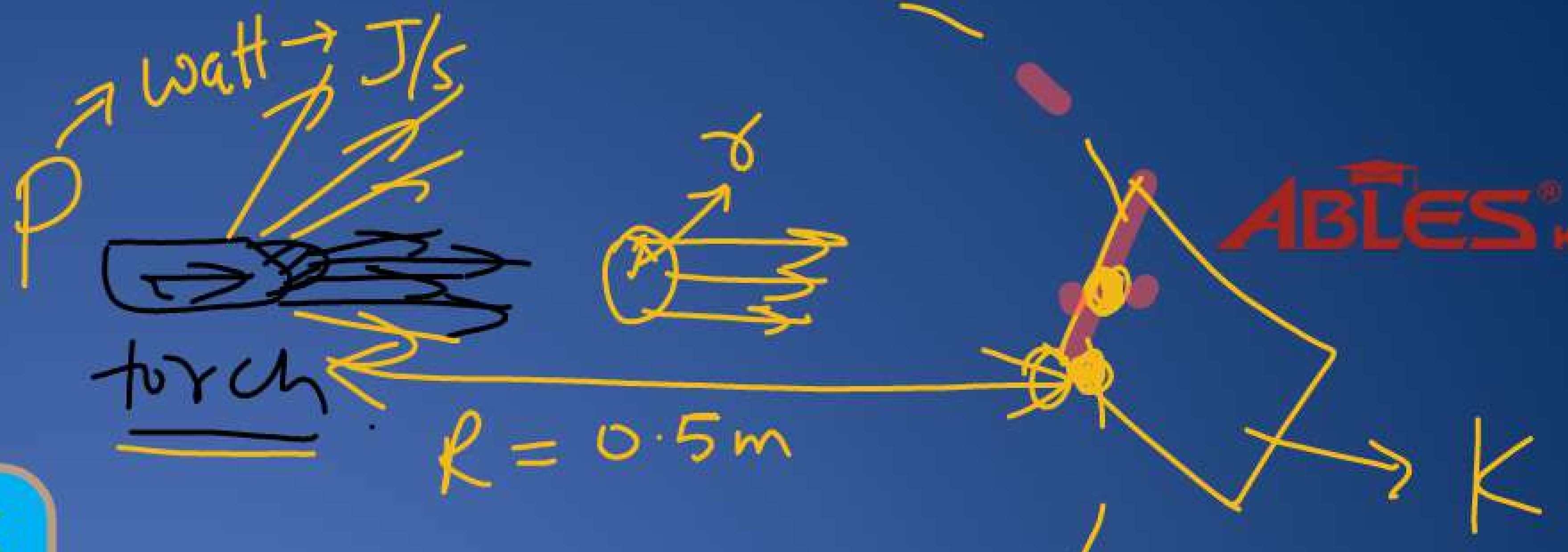
Sh -> What is Time Delay Perspective ?

G-> It is the minimum time that light wave would take to cause emission
Solve the following:



G-> P = 1.0 Watt. Potassium foil at R = 0.5 m. Assume wave nature of light beam with radius equal to the radius of K atom, r = 1.3 Å. Find time taken for e^- to come out. (ϕ_K = 2.2 eV)

A). 20.7 s	B). 1 μs
C). 10 s	D). 1 hour

$I = \frac{P}{A} = \frac{1.0}{4\pi R^2} = \frac{1}{4\pi(0.5)^2}$ W/m²

$r = 1.3$ Å $= 1.3\times10^{-10}$ m

$\phi = 2.2$ eV

$U = I \times \pi r^2 \times t_{min} = \phi$

$t_{min} = \frac{2.2\times1.6\times10^{-19}\times4\pi(0.5)^2}{1\times\pi\times(1.3\times10^{-10})^2}$

Sh-> How is wave and particle nature related?

G-> Light particle is called as photon. Its energy is related through the frequency of light wave

Each photon is an energy packet

$E_{photon} \propto f_{light\ wave}$