LENGTH CONTRACTION

1-3 Thursday
OH 127

$l = l'\sqrt{1-u^2/c^2}$ — l = stationary frame

$l' = l\sqrt{1-u^2/c^2}$ — l' = moving frame

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

u = velocity of moving frame

TIME DIALATION - Get Definition

$$\Delta t = \frac{\Delta t_0}{\sqrt{1-u^2/c^2}}$$

Δt_0 = observer rest frame

Δt = observer in moving frame

$$\Delta t' = \frac{\Delta t}{\sqrt{1-u^2/c^2}}$$

$\Delta t'$ = moving frame

Δt = rest

Lorentz - transformation

$$v' = \frac{v-u}{1-uv/c^2}$$

GAMMA

$$\gamma = \frac{1}{\sqrt{1-u^2/c^2}}$$

if $v' \to v$
then $u \to -u$

$$v = \frac{v'+u}{1+uv'/c^2}$$

TOTAL ENERGY (E)

$$E^2 = \underbrace{(mc^2)^2}_{\text{Rest Energy}} + \underbrace{(pc)^2}_{\text{Kinetic}}$$

$$E = \frac{mc^2}{\sqrt{1-v^2/c^2}}$$

Zero Rest Mass, $E = pc$

RELATIVISTIC MOMENTUM

$$p = \frac{mv}{\sqrt{1-v^2/c^2}}$$

$P = \gamma m v$

RELATIVISTIC KINETIC ENERGY

$$K = \frac{mc^2}{\sqrt{1-v^2/c^2}} - mc^2 = (\gamma-1)mc^2$$

DIFFERENCE IN TIME CLOCK

DESYNCHRONIZATION

$$\Delta t' - \Delta t = \frac{\Delta t (g) \Delta h}{c^2} \qquad g = 10\,\frac{m}{s^2}$$

$$\Delta t' - \Delta t = \left(-\frac{1}{2}\left(\frac{v}{c}\right)^2 + \frac{g\Delta h}{c^2}\right)\Delta t$$

usually used when comparing difference in age

FREQUENCY

$$f = \sqrt{\frac{1-v/c}{1+v/c}}\left(f_{\text{non-moving}}\right)$$

$f = v/\lambda$

PHOTOELECTRIC EFFECT

$$K_{MAX} = \begin{cases} 0 & f \leq f_0 \\ h(f-f_0) & f \geq f_0 \end{cases}$$

ENERGY OF A PHOTON

$E = hf \qquad h = 6.626 \times 10^{-34}$ Js

CONSERVATION OF ENERGY

$$hf = \underbrace{hf_0}_{\text{work function}} + K$$

CLASSIC MECHANICS

$$v = \sqrt{\frac{Ke^2}{m_e r}} \qquad K = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9\,\frac{Nm^2}{c^2}$$

$$E = -\frac{Ke^2}{2r} \qquad r: \text{radius}$$

$$r_n = \frac{n^2\hbar^2}{Ke^2 m_e} \qquad K = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9\,\frac{Nm^2}{C^2} \qquad \hbar = \frac{h}{2\pi}$$

BOHR QUANTIZATION

L = angular momentum

$L = m_e v r$ or $n\left(\frac{h}{2\pi}\right)$ $\qquad m_e v r = \frac{nh}{2\pi}$

$$E_n = \frac{-13.6\,eV}{n^2}$$

ENERGY LEVELS FOR HYDROGEN ATOM

$n \Rightarrow$ state 1, 2, 3...

$n=1 \Rightarrow$ Ground state

radii of Hydrogen atom

DEBROGLIE PARTICLE/WAVE DUALITY

$\lambda = \frac{h}{p} = \frac{h}{\gamma m v} = \frac{h}{mv}\sqrt{1 - v^2/c^2}$ = Perfect Constructive Interference

$f = \frac{E}{h} = \frac{mc^2}{\sqrt{1 - v^2/c^2}}$

$\underbrace{\Delta x}_{\text{difference in distance}} = n\lambda$

Stopping potential
- Found by making the potential of the anode relative to the cathode negative enough so that current stops.

COMPTON EFFECT

Compton scattering equation:

$\lambda' - \lambda = \frac{h}{m_e c}(1 - \cos\theta)$

λ = wavelength of photon before scattering

λ' = wavelength of photon after scattering

$\frac{1}{f'} - \frac{1}{f} = \frac{h}{m_e c^2}(1 - \cos\theta)$

Accelerating electrons: $K = e\Delta V$

non-relativistic electrons: $\lambda = \frac{h}{mv}$

$v = \sqrt{\frac{2K}{m}}$

Relativistic Electrons: $\lambda = \frac{h}{\gamma m v}$

$p = \sqrt{\frac{E^2}{c^2} - (mc)^2}$

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{\frac{K^2}{c^2} + 2Km}}$

Work Function - Represents minimum amount of energy necessary for an electron to escape from the surface

Constructive Interference

$d \sin\theta = n\lambda$

Length of spaceship divided by its rest length:

$t' = \ell t$

$\underbrace{\ell = t'/t}$

Now $\frac{1}{L} = \frac{1}{\ell}$ = answer

INTENSITY

$I = 4I_0 \cos^2\left(\frac{\pi d \sin\theta}{\lambda}\right)$

I gives probability that an individual electron would strike the screen at a given place

Momentum of photon = $\frac{\text{Energy}}{c}$

Photon - Carriers of electromagnetic radiation. Massless.

How much time passes $\Delta t = \frac{\Delta x}{V_0}$

Δx = distance

V_0 = velocity

$P(x,t) = |\psi(x,t)|^2 dx$

Running wave $\rightarrow$ $\psi(x,t) = \psi_0 e^{i(kx - \omega t)}$

$\int_{-\infty}^{\infty} P(x,t) = 1 \Rightarrow \int_{-\infty}^{\infty} |\psi(x,t)|^2 dx = 1$

$\text{mass}_{\text{proton}} = 1.67 \times 10^{-27}$ kg

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

$h = 6.626 \times 10^{-34}$ Js

CONSTANTS

$K = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{N \cdot m^2}{C^2}$

$m_e = 9.11 \times 10^{-31}$ kg

$1\,eV = 1.6 \times 10^{-19}$ J

$q_e = 1.6 \times 10^{-19}$ C