Prof. Carol Koleci
ck@wpi.edu
X 6018
conference email list: mcmi@wpi.edu

http://www.wpi.edu/~ck/teaching1.htm
→ PH1130, C08

I: Length Contraction

$$l = l_0 \sqrt{1 - \frac{u^2}{c^2}}$$

$$l' = l\sqrt{1 - \frac{u^2}{c^2}}$$

prime = denotes physical quantities in moving reference frame

unprimed = stationary reference frame

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

c = speed of light = 3.00×10^8 m/s
u = velocity of moving frame (example: car)

II: Time Dilation (page 1275)

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

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

$\boxed{37.6}$

$\boxed{\text{SUV}}$ moon

spaceracer: 0.8c past your SUV
a.) You measure spaceracer travels 1.2×10^8 m
t on race pilot = ? (find $\Delta t'$)

cont. → back

$$\Delta t = \frac{\Delta t'}{\gamma} = \frac{d}{u\gamma} = \frac{1.20\times10^{8}}{0.8c\gamma}$$

$\Delta t_0 = 0.300\text{s}$

PH1130
CONF.

1/27

Possibly Helpful Formulas:

$$\underbrace{E^2}_{\text{total energy}} = \underbrace{(mc^2)^2}_{\text{rest energy}} + \underbrace{(pc)^2}_{\text{kinetic}}$$

zero rest mass, $E = pc$

$$\vec{p} = \frac{m\vec{v}}{\sqrt{1-\frac{v^2}{c^2}}} = \gamma m\vec{v}$$

$$K = (\gamma - 1)mc^2$$

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

$$\Delta t = \frac{\Delta t'}{\sqrt{1-\frac{u^2}{c^2}}} = \gamma \Delta t'$$ (p. 1298)

PH1130

1/29

Possibly Helpful Formulas:

$$\Delta t' - \Delta t = \frac{\Delta t (g) \Delta h}{c^2}$$

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

$$f = \sqrt{\frac{1 - v/c}{1 + v/c}}\, f_{\text{non-moving}}$$

$g = 10\ m/s^2$

$T = 1/f$

$\Sigma \vec{F} = m\vec{a}$

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

* time is shorter when it is closer to the gravitational field

$1 + x + x^2 + x^3 + \ldots = \frac{1}{1-x} \quad |x| \ll 1$

$1 + 2x + 3x^2 + \ldots nx^{n-1} = \frac{1}{(1-x)^2}$ $\quad x \to -x \Rightarrow 1 - x + x^2 - x^3 \ldots \frac{1}{1+x}$

$(1-x)^{-n} \cong 1 + nx$

nano $= 10^{-9}$

Conference outline:

1.) Photoelectric Effect:

$$K_{max} = \begin{cases} 0 & f \le f_0 \\ h(f-f_0) & f \ge f_0 \end{cases}$$

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

Work function = Energy binded electrons needed to overcome $= hf_0$

2.) Conservation of Energy: $hf = \underbrace{hf_0}_{\text{Work function}} + \underset{\text{Kinetic energy}}{K}$

$E^2 = (mc^2)^2 + (K^2)$

$(K = (\gamma - 1)mc^2)$ $\boxed{E = \gamma mc^2}$

3.) Classic Mechanics: $\Sigma F = ma$

$F_e = F_c \Rightarrow \frac{ke^2}{r} = \frac{m_e v^2}{r} \quad (k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{Nm^2}{C^2})$

$\Rightarrow v = \sqrt{\frac{ke^2}{m_e r}}$

$E = \frac{1}{2} m_e v^2 - \frac{ke^2}{r} = \frac{-ke^2}{2r}$

4.) Bohr Quantization: $m_e v r = n\hbar$ or $L = n\frac{h}{2\pi}$

L = angular momentum $= m_e v r \quad \hbar = \frac{h}{2\pi}$

$r_n = \frac{n^2\hbar^2}{ke^2 m_e}$ (radii) $r_1 = 0.529 \text{ Å} \quad (1 \text{ Å} = 10^{-10} m)$

$E_n = \frac{-13.6 eV}{n^2} \qquad 1 eV = 1.6 \times 10^{-19} J$

conservation of Energy: $\Delta E = hf \Rightarrow hf = 13.6\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

DeBroglie particle/wave duality:

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

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

$\boxed{E = pc \text{ photon energy}}$

PH 1130
CONF.

2/10

Conference Formulas:

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

$\lambda = \frac{h}{p}$ perfect constructive interference:

$\Delta x = n\lambda$

↳ difference in distance

accelerating electrons: $K = e\Delta V$

non-relativistic electrons: $\lambda = \frac{h}{mv}$ $v = \sqrt{\frac{2K}{m}}$

Relativistic electrons: $\lambda = \frac{h}{\gamma mv}$ $E = K + mc^2$

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

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

E-field of wave: $\psi \sim 2\psi_0 \cos\left(\frac{\pi d \sin\theta}{\lambda}\right)$

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

$|\psi|^2 \rightarrow$ intensity of wave gives probability that an individual electron would strike the screen at a given place

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

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

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

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

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

hydrogen atom

$\Delta E = 13.6 eV \left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$

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