# *PHYSICS 6C FINAL EXAM FORMULAS*

## *Chapter 23: Electromagnetic Waves*

$EM\ waves: \quad c = 3.00\times10^{8}\ \text{m/s} \quad , \quad \varepsilon_0 = 8.85\times10^{-12}\ \text{C}^2/(\text{N}\cdot\text{m}^2) \quad , \quad \mu_0 = 4\pi\times10^{-7}\ \text{N/A}^2$

$c = 1/\sqrt{\varepsilon_0\mu_0} \quad , \quad E = cB \quad , \quad E = E_{\max}\sin 2\pi\left(\frac{t}{T}-\frac{x}{\lambda}\right) \quad , \quad B = B_{\max}\sin 2\pi\left(\frac{t}{T}-\frac{x}{\lambda}\right)$

$c = \lambda f \quad , \quad f = 1/T \quad , \quad k = 2\pi/\lambda \quad , \quad \omega = 2\pi f$

$Energy: \quad u = \frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2\mu_0}B^2 \quad , \quad B = \frac{E}{c} = \sqrt{\varepsilon_0\mu_0}E \quad , \quad u = \varepsilon_0 E^2$

$Energy\ flow\ per\ unit\ time\ per\ unit\ area: \quad S = cu \quad , \quad S_{av} = u_{av}c = \frac{1}{2}\varepsilon_0 c E_{\max}^2 = \frac{E_{\max}B_{\max}}{2\mu_0}$

$Intensity: \quad I = S_{av} \quad , \quad Radiation\ pressure = \frac{I}{c} \quad , \quad Momentum = \frac{\Delta U}{c}$

$Index\ of\ refraction: \quad n = \frac{c}{v} \quad , \quad \lambda = \frac{\lambda_0}{n} \quad , \quad Snell's\ law: \quad n_a\sin\theta_a = n_b\sin\theta_b \quad , \quad \sin\theta_{crit} = \frac{n_b}{n_a}$

$Polarization: \quad I = I_{\max}\cos^2\phi \quad , \quad Brewster's\ law: \quad \tan\theta_p = \frac{n_b}{n_a}$

## *Chapter 24: Geometric Optics*

$spherical\ mirrors: \quad \frac{1}{s}+\frac{1}{s'} = \frac{1}{f} \quad , \quad f = \frac{R}{2} \quad , \quad m = \frac{y'}{y} = -\frac{s'}{s}$

Refarction at a spherical surface: $\frac{n_a}{s}+\frac{n_b}{s'} = \frac{n_b-n_a}{R} \quad , \quad m = \frac{y'}{y} = -\frac{n_a s'}{n_b s}$

$Thin\ Lenses: \quad \frac{1}{s}+\frac{1}{s'} = \frac{1}{f} \quad , \quad \frac{1}{f} = (n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad , \quad m = \frac{y'}{y} = -\frac{s'}{s}$

## *Chapter 25: Optical Instruments*

$M(angular) = \frac{\theta'}{\theta}$; $Magnifier: \ M(relaxed\ eye) = \frac{d}{f}$ , Near point: $d$ = 25cm for normal eye

$Microscope: \quad M = m_1 M_2 \quad , \quad m_1 = -\frac{s_1'}{s_1} \quad , \quad M_2 = \frac{d}{f_2}$ ; Approximate result: $M \cong \frac{(25\text{cm})s_1'}{f_1 f_2}$

## *Chapter 26: Interference and Diffraction*

1 nm = $10^{-9}$m ; 1 $\mu$m = $10^{-6}$m

Two slit interference: $d\sin\theta = m\lambda \quad m = 0,\ \pm1,\ \pm2,\ \pm3,....$ (*constructive*)

When $R >> d \quad y_m = R\frac{m\lambda}{d}$ (*constructive*)

$d\sin\theta = (m+1/2)\lambda \quad m = 0,\ \pm1,\ \pm2,\ \pm3,....$ (*destructive*)

When $R >> d \quad y_m = R\frac{(m+1/2)\lambda}{d}$ (*destructive*)

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*Thin films* (*constructive interference*): $\lambda_n = \lambda/n$

$2t = m\lambda_n \quad m = 1, 2, 3, \ldots$ (*if no relative phase change between the two waves*)

$2t = (m + 1/2)\lambda_n \quad m = 0, 1, 2, 3, \ldots$ (*if* $180^0$ *relative phase change between the two waves*)

*Single slit diffraction minima:*

$a \sin\theta = m\lambda \quad m = \pm 1, \pm 2, \pm 3, \ldots$ ; for small $\theta$: $y_m = R\frac{m\lambda}{a}$

*Diffraction grating maxima:* $d \sin\theta = m\lambda \quad m = 0, \pm 1, \pm 2, \pm 3, \ldots$

*Circular aperture diffraction minima:*

$\sin\theta_1 = 1.22\frac{\lambda}{D}$ ; $\sin\theta_2 = 2.23\frac{\lambda}{D}$ ; $\sin\theta_3 = 3.24\frac{\lambda}{D}$

*Resolution*: $\theta_{res} = 1.22\frac{\lambda}{D}$ , *if*: $\Delta\theta < \theta_{res}$ (*not resolved*)

$\Delta\theta = \theta_{res}$ (*barely resolved*)

$\Delta\theta > \theta_{res}$ (*resolved*)

***Chapter 27: Relativity***

*Time dilation*: $\Delta t = \frac{\Delta t_0}{\sqrt{1 - u^2/c^2}}$ ; *Length contraction:* $l = l_0\sqrt{1 - u^2/c^2}$

*Relativistic velocity transformation:* $v' = \frac{v - u}{1 - uv/c^2}$ ; $v = \frac{v' + u}{1 + uv'/c^2}$

*Relativistic momentum:* $\vec{p} = \frac{m\vec{v}}{\sqrt{1 - v^2/c^2}}$ ; *Relativistic KE:* $K = \frac{mc^2}{\sqrt{1 - v^2/c^2}} - mc^2$

*Total energy:* $E = K + mc^2 = K + E_{rest} = \frac{mc^2}{\sqrt{1 - v^2/c^2}}$ ; $E_{rest} = mc^2$

*Relativistic energy-momentum relation:* $E^2 = \left(mc^2\right)^2 + \left(pc\right)^2$

*Energy and momentum of a massless particle:* $E = pc$

***Chapter 28: Photons, Electrons, and Atoms***

*Photons:* $E = hf$ ; $\lambda = \frac{c}{f}$ ; $p = \frac{E}{c} = \frac{h}{\lambda}$

*Photoelectric:* $\frac{1}{2}mv_{\max}^2 = eV_0$ ; $\frac{1}{2}mv_{\max}^2 = hf - \phi$

*Compton effect*: $\Delta\lambda = \lambda' - \lambda = \frac{h}{mc}\left(1 - \cos\phi\right)$; $K = hf - hf'$

*Bohr Model:* $L = mvr = n\frac{h}{2\pi}, \quad n = 1, 2, 3, \cdots$

$hf = E_i - E_f$ ; $r_n = \varepsilon_0\frac{n^2h^2}{\pi me^2} = (0.05293nm) \times n^2$

$\varepsilon_0 = 8.854 \times 10^{-12}\ \mathrm{C^2/(N\text{-}m^2)}$

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| $1\ \mathrm{eV} = 1.602 \times 10^{-19}\ \mathrm{J}$ |
| $\mathrm{k} = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9\ \mathrm{N - m^2 / C^2}$ |
| $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{T - m / A}$ |
| $\mathrm{c} = 2.998 \times 10^8\ \mathrm{m/s}$ |
| $\mathrm{h} = 6.626 \times 10^{-34}\ \mathrm{J - s}$ |
| $\mathrm{e} = 1.602 \times 10^{-19}\mathrm{C}$ |
| $\mathrm{m_e} = 9.109 \times 10^{-31}\mathrm{Kg}$ |
| $1\mathrm{nm} = 10^{-9}\mathrm{m}$ |
| $1\ \overset{0}{\mathrm{A}} = 10^{-10}\mathrm{m}$ |

$$v_n = \frac{1}{\varepsilon_0}\frac{e^2}{2nh} \quad ; \quad E_n = -\frac{1}{\varepsilon_0^2}\frac{me^4}{8n^2h^2} = -\frac{13.6\text{eV}}{\text{n}^2}, \quad n = 1, 2, 3, \cdots$$

$$K_n = \frac{1}{2}mv_n^2 \quad ; \quad U_n = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n} \quad ; \quad E_n = K_n + U_n$$

*Spectral series:* $\frac{1}{\lambda} = R\left(\frac{1}{n'^2} - \frac{1}{n^2}\right)$ ; $n > n' = 1, 2, 3, \cdots$ ; $R = 1.097 \times 10^7 \text{ m}^{-1}$

$$hcR = 13.6 \text{ eV} \quad ; \quad R = \frac{me^4}{8\varepsilon_0 h^3 c}$$

*De Broglie wavelength:* $\lambda = \frac{h}{p}$ ; $p = mv$ *if* $v \ll c$ *, otherwise use relaitivity!*

*Uncertainty Principle:* $\Delta x \Delta p \geq \hbar \qquad \hbar = h/2\pi$

***Chapter 29: Atoms***

*Angular momentum:* $L = \sqrt{l(l+1)}\frac{h}{2\pi} \quad (l = 0, 1, 2, \cdots, n-1) \qquad \hbar = \frac{h}{2\pi}$

$L_z = m_l \frac{h}{2\pi} \quad (m_l = 0, \pm1, \pm2, \cdots, \pm l)$ ; *Spin:* $S_z = s\hbar$ ; $s = \pm\frac{1}{2}$ ; $S = \frac{\sqrt{3}}{2}\hbar$

***Chapter 30: Nuclear Physics***

$R = R_0 A^{1/3}$ ; $R_0 = 1.2 \times 10^{-15} \text{m} = 1.2 \text{ fm}$ ; $1\text{fm} = 10^{-15}\text{m}$

$m_p = 1.67262171 \times 10^{-27}\text{kg}$ ; $m_n = 1.67492728 \times 10^{-27}\text{kg}$

$m_p = 1.00727646688$ u ; $m_n = 1.00866491560$ u ; $m_e = 0.00054857990945$ u

$m({}_1^1H) = 1.0078250$ u ; $1 \text{ u} = 931.494 \text{ MeV/c}^2$

*Mass defect:* $\Delta M = Zm_p + Nm_n - M$ ; *Binding energy:* $E_B = (\Delta M)c^2$

*Rate of decay:* $\frac{\Delta N}{\Delta t} = -\lambda N$ ; *Number of radioactive nuclei after time t:* $N = N_0 e^{-\lambda t}$

*Activity:* $a = |\Delta N/\Delta t| = \lambda N$ ; $a = a_0 e^{-\lambda t}$

*Decay constant and half-life:* $T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$

*Lifetime (or mean lifetime):* $T_{mean} = \frac{1}{\lambda} = \frac{T_{1/2}}{\ln 2} = \frac{T_{1/2}}{0.693}$ ;

$1 \text{ Ci} = 3.70 \times 10^{10}$ decays/s ; 1Bq = 1 decay/s

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**BRING A PINK SCANTRON FORM ParSCORE TO THE EXAM ON FRIDAY DECEMBER 11 (noon – 3:00)**

**BRING A #2 PENCIL, A PEN AND A SCIENTIFIC CALCULATOR AND A PICTURE ID**

**THE EXAM IS CLOSED BOOK CLOSED NOTES AND CLOSED PROBLEMS. ONLY THIS FORMULA SHEET WILL BE ALLOWED WITH NOTHING WRITTEN ON EITHER SIDE OR ON ANY OTHER SHEET**