PHYSICS 2220 — Final Exam Equation Sheet

1. $k = 8.99 \times 10^9$ N·m²/C² $\quad \varepsilon_\circ = 8.85 \times 10^{-12}$ C²/N·m² $\quad \mu_\circ = 4\pi \times 10^{-7}$ T·m/A
   $e = 1.60 \times 10^{-19}$ C $\quad$ 1 eV $= 1.60 \times 10^{-19}$ J $\quad g = 9.8$ m/s² $\quad$ 1 yr $= 3.16 \times 10^7$ s
   $c = 3 \times 10^8$ m/s $=$ 1 ly/yr $\quad h = 6.63 \times 10^{-34}$ J·s $\quad \hbar = h/2\pi \quad a_\circ = 0.0529$ nm
   $hc = 1240$ eV·nm $\quad$ 1 u $= 1.661 \times 10^{-27}$ kg $\quad uc^2 = 931.5$ MeV
   electron mass $m_e = 9.11 \times 10^{-31}$ kg $\quad$ proton mass $m_p = 1.67 \times 10^{-27}$ kg
   Circle: $C = 2\pi r \quad A = \pi r^2 \quad$ Sphere: $A = 4\pi r^2 \quad V = \frac{4}{3}\pi r^3$
   Cylinder: $A = \pi r^2$ (end) $\quad A = 2\pi r\ell$ (side) $\quad V = \pi r^2 \ell$

2. Coulomb's law: $F = k\,\frac{|q_1||q_2|}{r^2} \qquad k = \frac{1}{4\pi\varepsilon_\circ} \qquad \mathbf{F} = q\mathbf{E}$

3. Gauss' law: $\Phi_c = \oint \mathbf{E}\cdot d\mathbf{A} = \oint E\,dA\,\cos\theta = \frac{q_{\text{enc}}}{\varepsilon_\circ}$

4. $\Delta V = V_B - V_A = -\int_A^B \mathbf{E}\cdot d\mathbf{s} = -\int_A^B E\,ds\,\cos\theta$

5. $\Delta U = U_B - U_A = q(V_B - V_A) = q\Delta V$

   $\Delta U = U_B - U_A = -q\int_A^B \mathbf{E}\cdot d\mathbf{s} = -q\int_A^B E\,ds\,\cos\theta$

6. For point charge: $E = k\,\frac{|q|}{r^2} \qquad V = k\,\frac{q}{r} \qquad U = k\,\frac{q_1 q_2}{r}$

7. $C = \frac{Q}{\Delta V} \qquad C = \frac{\varepsilon_\circ A}{d} \qquad \Delta V = Ed \qquad$ Parallel: $C_{\text{eq}} = C_1 + C_2 + \ldots$

   Series: $\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2}\ldots$ or $C_{\text{eq}} = \frac{C_1 C_2}{C_1 + C_2}$ (2 only)

8. $V = iR \qquad P = iV = i^2R = \frac{V^2}{R} \qquad R = \frac{\rho L}{A} \qquad$ Parallel: $\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

   $R_{\text{eq}} = \frac{R_1 R_2}{R_1 + R_2}$ (2 only) $\qquad$ Series: $R_{\text{eq}} = R_1 + R_2 + \ldots$

9. Kirchhoff's rules: 1) current in = current out; 2) sum of voltage rises and drops = 0 around a closed loop

10. $q = q_\circ e^{-t/RC} \qquad q = q_\circ\left(1 - e^{-t/RC}\right) \qquad i = i_\circ e^{-t/RC} \qquad \tau = RC$

11. $U_C = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}QV \qquad u_E = \frac{1}{2}\varepsilon_\circ E^2 \qquad U_L = \frac{1}{2}Li^2 \qquad u_B = \frac{1}{2\mu_\circ}B^2$

12. $\mathbf{F}_B = q\mathbf{v}\times\mathbf{B} \qquad |\mathbf{F}_B| = |q||\mathbf{v}||\mathbf{B}|\sin\phi \qquad \mathbf{F} = q\mathbf{E} + q\mathbf{v}\times\mathbf{B} \qquad r = \frac{mv}{qB} \qquad T = \frac{1}{f} = \frac{2\pi r}{v}$

13. $\mathbf{F}_B = i\mathbf{L}\times\mathbf{B} \qquad |\mathbf{F}_B| = i|\mathbf{L}||\mathbf{B}|\sin\phi \qquad \tau = NiAB\sin\theta$

14. Biot-Savart law: $\mathbf{B} = \frac{\mu_\circ i}{4\pi}\int \frac{d\mathbf{s}\times\hat{r}}{r^2} = \frac{\mu_\circ i}{4\pi}\int \frac{ds\sin\theta}{r^2}$

15. Ampere's law: $\oint \mathbf{B} \cdot d\mathbf{s} = \oint B\,ds\,\cos\theta = \mu_\circ i$

16. Faraday's law: $\mathcal{E} = -N\dfrac{d\Phi_B}{dt} = -N\dfrac{\Delta(BA\cos\theta)}{\Delta t}$ $\quad \mathcal{E} = -L\dfrac{di}{dt}$

    Inductance: $L = \dfrac{N\Phi_B}{i}$ $\quad$ Solenoid: $B = \mu_\circ n i$ $\quad L = \mu_\circ n^2 A\ell$ $\quad n = \dfrac{N}{\ell}$

17. RL: $i = \dfrac{\mathcal{E}}{R}(1 - e^{-Rt/L})$ $\quad i = \dfrac{\mathcal{E}}{R}e^{-Rt/L}$ $\quad \tau = \dfrac{L}{R}$

18. RLC circuit: $V_R = I_m R$ $\quad V_L = I_m X_L$ $\quad V_C = I_m X_C$ $\quad \omega = 2\pi f$ $\quad X_L = \omega L$ $\quad X_C = \dfrac{1}{\omega C}$

    $Z = \sqrt{R^2 + (X_L - X_C)^2}$ $\quad I_m = \dfrac{\mathcal{E}_m}{Z}$ $\quad \omega_\circ = \dfrac{1}{\sqrt{LC}}$ $\quad I_{\text{rms}} = \dfrac{I_m}{\sqrt{2}}$ $\quad \mathcal{E}_{\text{rms}} = \dfrac{\mathcal{E}_m}{\sqrt{2}}$

19. $I = I_\circ \cos^2\theta$ $\quad$ reflection: $\theta = \theta'$ $\quad$ refraction: $n_1 \sin\theta_1 = n_2 \sin\theta_2$

    $n = \dfrac{c}{v}$ $\quad f\lambda = v$ $\quad n_1\lambda_1 = n_2\lambda_2$ $\quad \sin\theta_c = \dfrac{n_2}{n_1}$

20. $\dfrac{1}{f} = (n-1)\left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right)$ (lenses) $\quad f = \dfrac{R}{2}$ (mirrors) $\quad \dfrac{1}{p} + \dfrac{1}{i} = \dfrac{1}{f}$ $\quad m = \dfrac{h'}{h} = -\dfrac{i}{p}$

21. double slits: $d\sin\theta = m\lambda$ $\quad m = 0, 1, 2, 3, \ldots$ (max); order $= m$

    $d\sin\theta = (m + \frac{1}{2})\lambda$ $\quad m = 0, 1, 2, 3, \ldots$ (min); order $= m + 1$ $\quad \sin\theta = \dfrac{y}{D}$ (small θ)

22. single slit: $a\sin\theta = m\lambda$ $\quad m = 1, 2, 3, \ldots$ (min); order $= m$

23. for θ in radians: $\theta_{\text{min}} = \dfrac{\lambda}{a}$ (slit) $\quad \theta_{\text{min}} = \dfrac{1.22\lambda}{d}$ (circular)

24. diffraction grating: $d\sin\theta = m\lambda$ $\quad m = 0, 1, 2, 3, \ldots$ (max); order $= m$

25. $\Delta t_{\text{moving}} = \dfrac{\Delta t_{\text{rest}}}{\sqrt{1 - v^2/c^2}}$ $\quad L_{\text{moving}} = L_{\text{rest}}\sqrt{1 - v^2/c^2}$ $\quad u'_x = \dfrac{u_x - v}{1 - u_x v/c^2}$

26. $\gamma = \dfrac{1}{\sqrt{1 - u^2/c^2}}$ $\quad K = mc^2(\gamma - 1)$ $\quad E = \gamma mc^2$ $\quad E^2 = p^2c^2 + m^2c^4$ $\quad p = \gamma mu$

27. $E_{\text{photon}} = hf = \dfrac{hc}{\lambda} = pc$ $\quad K_{\text{max}} = E_{\text{photon}} - \Phi$ $\quad \Delta\lambda = \dfrac{h}{m_e c}(1 - \cos\theta)$

28. $p = mv$ (except photons) $\quad \lambda = \dfrac{h}{p}$ $\quad \Delta x \Delta p \simeq \hbar$ $\quad$ For estimates, $p_{\text{min}} \simeq \Delta p$

29. $E_n = \left(\dfrac{h^2}{8mL^2}\right)n^2$ $\quad E_n = -13.6\ \text{eV}\dfrac{1}{n^2}$ $\quad E_{\text{photon}} = E_{\text{high}} - E_{\text{low}}$

30. $N = N_\circ e^{-\lambda t}$ $\quad R = N\lambda$ $\quad R = R_\circ e^{-\lambda t}$ $\quad \tau = \dfrac{\ln 2}{\lambda}$

31. $E_{\text{binding}} = [Zm_H + Nm_n - M(^A_Z X)]c^2$ $\quad Q = [(\text{masses in}) - (\text{masses out})]c^2$