

PHYSICS 2220 — Final Exam Equation Sheet

1. $k = 8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$ $\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$ $\mu_0 = 4\pi \times 10^{-7} \text{ T}\cdot\text{m}/\text{A}$
 $e = 1.60 \times 10^{-19} \text{ C}$ $1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$ $g = 9.8 \text{ m}/\text{s}^2$ $1 \text{ yr} = 3.16 \times 10^7 \text{ s}$
 $c = 3 \times 10^8 \text{ m}/\text{s} = 1 \text{ ly}/\text{yr}$ $h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s}$ $\hbar = h/2\pi$ $a_0 = 0.0529 \text{ nm}$
 $hc = 1240 \text{ eV}\cdot\text{nm}$ $1 \text{ u} = 1.661 \times 10^{-27} \text{ kg}$ $uc^2 = 931.5 \text{ MeV}$
electron mass $m_e = 9.11 \times 10^{-31} \text{ kg}$ proton mass $m_p = 1.67 \times 10^{-27} \text{ kg}$
Circle: $C = 2\pi r$ $A = \pi r^2$ Sphere: $A = 4\pi r^2$ $V = \frac{4}{3}\pi r^3$
Cylinder: $A = \pi r^2$ (end) $A = 2\pi r\ell$ (side) $V = \pi r^2\ell$
2. Coulomb's law: $F = k \frac{|q_1||q_2|}{r^2}$ $k = \frac{1}{4\pi\epsilon_0}$ $\mathbf{F} = q\mathbf{E}$
3. Gauss' law: $\Phi_c = \oint \mathbf{E} \cdot d\mathbf{A} = \oint E dA \cos\theta = \frac{q_{\text{enc}}}{\epsilon_0}$
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: $E = k \frac{|q|}{r^2}$ $V = k \frac{q}{r}$ $U = k \frac{q_1q_2}{r}$
7. $C = \frac{Q}{\Delta V}$ $C = \frac{\epsilon_0 A}{d}$ $\Delta V = Ed$ Parallel: $C_{\text{eq}} = C_1 + C_2 + \dots$
Series: $\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} \dots$ or $C_{\text{eq}} = \frac{C_1 C_2}{C_1 + C_2}$ (2 only)
8. $V = iR$ $P = iV = i^2 R = \frac{V^2}{R}$ $R = \frac{\rho L}{A}$ Parallel: $\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$
 $R_{\text{eq}} = \frac{R_1 R_2}{R_1 + R_2}$ (2 only) Series: $R_{\text{eq}} = R_1 + R_2 + \dots$
9. Kirchhoff's rules: 1) current in = current out; 2) sum of voltage rises and drops = 0 around a closed loop
10. $q = q_0 e^{-t/RC}$ $q = q_0 (1 - e^{-t/RC})$ $i = i_0 e^{-t/RC}$ $\tau = RC$
11. $U_C = \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} QV$ $u_E = \frac{1}{2} \epsilon_0 E^2$ $U_L = \frac{1}{2} Li^2$ $u_B = \frac{1}{2\mu_0} B^2$
12. $\mathbf{F}_B = q\mathbf{v} \times \mathbf{B}$ $|\mathbf{F}_B| = |q||\mathbf{v}||\mathbf{B}| \sin\phi$ $\mathbf{F} = q\mathbf{E} + q\mathbf{v} \times \mathbf{B}$ $r = \frac{mv}{qB}$ $T = \frac{1}{f} = \frac{2\pi r}{v}$
13. $\mathbf{F}_B = i\mathbf{L} \times \mathbf{B}$ $|\mathbf{F}_B| = i|\mathbf{L}||\mathbf{B}| \sin\phi$ $\tau = NiAB \sin\theta$
14. Biot-Savart law: $\mathbf{B} = \frac{\mu_0 i}{4\pi} \int \frac{d\mathbf{s} \times \hat{r}}{r^2} = \frac{\mu_0 i}{4\pi} \int \frac{ds \sin\theta}{r^2}$

15. Ampere's law: $\oint \mathbf{B} \cdot d\mathbf{s} = \oint B ds \cos \theta = \mu_0 i$

16. Faraday's law: $\mathcal{E} = -N \frac{d\Phi_B}{dt} = -N \frac{\Delta(BA \cos \theta)}{\Delta t}$ $\mathcal{E} = -L \frac{di}{dt}$
 Inductance: $L = \frac{N\Phi_B}{i}$ Solenoid: $B = \mu_0 ni$ $L = \mu_0 n^2 A \ell$ $n = \frac{N}{\ell}$

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

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

$$Z = \sqrt{R^2 + (X_L - X_C)^2} \quad I_m = \frac{\mathcal{E}_m}{Z} \quad \omega_0 = \frac{1}{\sqrt{LC}} \quad I_{\text{rms}} = \frac{I_m}{\sqrt{2}} \quad \mathcal{E}_{\text{rms}} = \frac{\mathcal{E}_m}{\sqrt{2}}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

30. $N = N_o e^{-\lambda t}$ $R = N\lambda$ $R = R_o e^{-\lambda t}$ $\tau = \frac{\ln 2}{\lambda}$

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