Sem II 97-98

# PHYSICS 208 COURSE OUTLINE

| | | | 4th ed. Resnick, Halliday, Walker |
|---|---|---|---|
| Wed Jan. 21 | Charge | Chap 23 | 5,7,11,13,17,19,23,29,31,35 |
| Lab | None | | |
| Mon Jan. 26 | Electric Field | Chap 24 | 15,19,27,29,30,33,45,49.55,57 |
| Lab | None | | |
| Wed Jan. 28 | Gauss' Law | Chap 25 | 3,9,11,13,19,27,37,39,46,47,54 |
| Mon Feb. 2 | Potential | Chap 26 | 11,R13,23,27,33,35,39,41,49,55,67, 81,R85 |
| Lab E1 | Electroscope, Electrometer | | |
| Wed Feb. 4 | Capacitance | Chap 27 | 7,R14,17,19,25,27,29,43,45,49,51 |
| Mon Feb. 9 | Dielectrics | Chap 27 | 55,57,61,63,65,67,69,71 |
| | | Chap 26 | 90 Ans:$F = (1/4\pi\epsilon_0)q^2/(2d)^2$, 91 Ans:$Q_1 = QR_1/(R_1 + R_2)$ |
| Lab E2 | Fields, Equipotentials | | |
| Wed Feb. 11 | Current, Resistance | Chap 28, | 9,13,19,29,37,41,53,57,61,63 |
| Fri Feb. 13 | **HOUR EXAM** | | |
| Mon Feb. 16 | D.C. Circuits | Chap 29 | 11,19,25,29,33,37,39,41,43 |
| Lab E3 | Capacitance, RC | | |
| Wed Feb. 18 | Electrical Instruments | Chap 29 | 45,49,53,57,61,65,69,71,73,75 |
| Mon Feb. 23 | Magnetic Field | Chap 30 | 3,5a,9,11,17,R31,35,39,45,47,59,61,67 |
| Lab E4-E5 | Bridge, Potentiometer | | |
| Wed Feb. 25 | Ampere's Law | Chap 31 | 9,11,15,29,35,45,47,51,53,R57,65,71 |
| Mon Mar. 2 | Faraday's Law | Chap 32 | 5,11,15,17,23,25,27,29,35b,43, 48 $v = mgR/B^2L^2$ |
| Lab E6 | e/m ratio | | |
| Wed Mar. 4 | Inductance | Chap 33 | 5,6,9a,11,19,21,25,33,35,45,47,49,50 |
| Mon Mar. 16 | Magnetism, Matter | Chap 34 | 3,5,7,19,23,31,R33(a)toward P2 |

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|---|---|---|---|
| | | | (b)toward P1, (c)hits P1 |
| Lab E7 | Faraday & Lenz' Law | | |
| Wed Mar. 18 | Oscillations | Chap 35 | 3,7,15,19,29,33,35,37 |
| Fri Mar. 20 | **HOUR EXAM** | | |
| Mon Mar. 23 | A.C. Circuits | Chap 36 | 7,11,15,23,29,31(3,13),35,R37,39,43,45 |
| Lab E8 | Oscilloscope | | |
| Wed Mar. 25 | Maxwell's Equations | Chap 37 | 3,9,11,13,19,23 |
| Mon Mar. 30 | E.M. Waves | Chap 38 | 3,11,15,17,27,35,41,R43,R47,51,55,59 |
| Lab E9 | Resonant Circuit | | |
| Wed Apr. 1 | Geometrical Optics | Ch 39 1012-1024 | 3,R6,9,R13,R14,19,R25, 27a,31,33 35,R37,41,43,R45,49 |
| Mon Apr. 6 | Optical Instruments | Ch 39 1025-1035 | 51,R55,57,R61,R64,67,69, 71,73 R75,77,79,81,83 |
| Lab L2 | Mirrors, Lenses | | |
| Wed Apr. 8 | Optical Interference | Chap 40 | R9,11,15,23,27,R35,39,43,49,R51, 63,69,R77,79 |
| Mon Apr. 13 | Diffraction | Chap 41 | 7,R9,13,R14,17,25,33,41,45,63,77 |
| Lab L3 | Optical Instruments | | |
| Wed Apr. 15 | Relativity | Notes | |
| Fri Apr. 17 | **HOUR EXAM** | | |
| Mon Apr. 20 | Relativity | Notes | |
| Lab L1+L9 | Wavelength of Laser light | | |
| Wed Apr. 22 | Bohr Atom | Chap 43 | 3,15,R28,31,43,R49,51,61,69,77 |
| Mon Apr. 27 | Complex Atoms | Chap 44-45 | 44: 3,11,21,45,R47<br>45: 5,9,31,35,39,49,69 |
| Lab L8 | Polarization | Chap. 26, Shortley-Williams | |
| Wed Apr. 29 | Conductors | Chap 46 | 19(see prob.10 for b),31,39 |
| Mon May 4 | Nuclear Physics | Chap 47-48 | 47:1,5,R9,R19,13,17,27,R39,R41, 53,63,67 |

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|---|---|---|---|
| | | | 48:3,39,43,47 |
| Lab | H Spectrum | | |
| Wed May 6 | Particle Physics | Chap 49 | 7,31 |
| Wed May 13 | 2:45 pm **FINAL EXAM** | | 2650 Humanities Bldg |

Sem II
97-98

# PHYSICS 208 REVIEW SHEET

## 1st Exam: 13-Feb-98

1. Electrostatics. Coulomb's Law for point charges. How one would go about calculating forces due to finite charge distributions, like a ring charge or line charge. Forces due to spherical shell charge inside and outside the shell. Charging by friction, by induction. Difference in behavior of charges on insulators and conductors.

2. Electric Fields. $E = F/q$ force per unit charge. Dipole. Field along a dipole axis. Torque on a dipole $\vec{T} = \vec{p} X \vec{E}$. Potential energy of a dipole $PE = -\vec{p} \cdot \vec{E}$. Force on a dipole which has $\vec{E}$ and $\vec{p}$ along the z axis $F_z = p_z \partial E/\partial z$.

3. Gauss' Law. Apply Gauss' Law to get the electric field for cases of (1) plane symmetry: infinite non conducting plane and two infinite parallel conducting planes, (2) cylindrical symmetry: infinite line charge, non conducting cylinder inside and outside, concentric cylinders and shells (conducting and nonconducting) at all radii, (3) spherical symmetry: inside and outside spherical charge distributions, spherical shells (conducting and nonconducting). Field very close to a conductor $E = \sigma/\epsilon_0$. Static $E = 0$ inside a conductor. Large fields near conducting surface with large curvature. Plasma force between oppositely charged surfaces and plasma oscillation.

4. Electric Potentials $V = W/q$ work or potential energy per unit charge. Units=Volts. $V = -\int_a^b \vec{E} \cdot \vec{ds}$ is independent of path. Equipotential surfaces must be perpendicular to $\vec{E}$. $E_s = -dV/ds$ can be used to get components of $\vec{E}$ along some direction $\vec{s}$. Example: $E_\theta$ and $E_r$ components of a dipole field. Potentials from different charges simply add. Potential of a dipole. Potential Energy of an assembly of charges (distinguished from potential due to an assembly of charges).

5 Capacitance. $C = Q/V$ is a geometrical property of a conductor. Calculate C for various geometries: sphere, parallel plates, concentric cylinders, concentric spheres. Effective capacitance for capacitors connected in parallel and series. Calculate V across capacitors connected in series and Q stored on capacitors connected in parallel. Energy stored in a capacitor $PE = (1/2)CV^2 = Q^2/2C$. Energy per unit volume stored in a field $u = (1/2)\epsilon_0 E^2$. Electrostatic pressure p=u. Marx generator.

6 Dielectrics. Incorporation of dielectrics into electrostatic equations. $\epsilon = \kappa\epsilon_0$ How dipole effects reduce electric field. Revised Coulomb Law and Gauss' Law using $\epsilon$ in place of $\epsilon_0$. Calculation of capacitance for cases with different dielectrics (different $\kappa$'s and different geometries). Force on the dielectric. Insert dielectrics into capacitors with V constant or with Q constant and describe the changes.

## PHYSICS 208 REVIEW SHEET

**2nd Exam: 20-March-98**

Review Wednesday 7-9pm 2327 Sterling (P. Krastev)

Review Wednesday 6-7:30pm 3331 Sterling (D. Zeppenfeld)

Last minute questions Friday 7-8-(?)pm 4279 Chamberlin (A. Erwin)

1. Currents and Resistance. Direction of current given by the flow of *positive* charge. Ohm's Law $V = iR$. $R = \rho\ell/A$ where $\rho$ is the resistivity of a conducting material. Microscopic Ohm's Law $J = \sigma E$. Conductivity is $\sigma = 1/\rho$. Drift velocity $v_d$. $\vec{J} = ne\vec{v}_d$. Power: $P = iV = V^2/R = i^2R$. Temperature dependence of resistivity: $(d\rho/\rho_o)/dT = \alpha$, where $d\rho = \rho - \rho_o$ and $dT = T - T_o$.

2. Circuits. Write equation for work on a unit charge taken around a loop. Assignment of current direction and potential difference signs to electrical components. Reduce combinations of resistors in series or parallel into a single effective resistor. Parallel: $1/R_{eff} = 1/R_1 + 1/R_2$. Series: $R_{eff} = R_1 + R_2$. Be able to write down all necessary Kirchhoff equations for multiloop circuits with more than one voltage source. Voltmeters, Ohmmeters, potentiometers, Wheatstone bridge. Voltage divider theorem. Current divider theorem.

3. Time constants. R-C time constant $\tau = RC$. Charging and discharging equations for q and i. L-R time constant. $\tau = L/R$. Exponential rise and fall equations for current.

4. Magnetic Field. Lorentz force equation $\vec{F} = q\vec{v}X\vec{B}$. Particle motion in crossed E and B fields. Hall effect voltage and how it distinguishes sign of charge carriers and how it can be used to measure magnetic fields. Spiral motion of a charged particle in a uniform magnetic field. Derive the cyclotron frequency and radius. Force on a wire $\vec{F} = id\vec{\ell}X\vec{B}$. Magnetic dipole moment of a loop $\vec{\mu} = I\vec{A}$. (Direction of $\vec{\mu}$ given by a Right Hand Rule)

Torque on a dipole $\vec{\tau} = \vec{\mu} X \vec{B}$. Potential energy of a dipole $U = -\vec{\mu} \cdot \vec{B}$. Force on a dipole in a field and a gradient along z $\vec{F_z} = \mu_z \partial B_z / \partial z$.

5. Calculating Fields. Biot-Savart Law for force

$$d\vec{F}_{21} = (\mu_o/4\pi) i_2 d\vec{s}_2 X (i_1 d\vec{s}_1 X \hat{r}_{12})/r^2$$

$d\vec{B}_{21} = (\mu_o/4\pi)(i_1 d\vec{s}_1 X \hat{r}_{12})/r^2$ where $\hat{r}_{12}$ is a unit vector going from $ds_1$ to $ds_2$ and $dF_{21}$ is the force on $ds_2$ due to $ds_1$. (Direction of $d\vec{B}$ agrees with the Right Hand Rule.) Field at center of a circular arc of current (including a complete circle). Ampere's Law $\oint \vec{B} \cdot d\vec{s} = \mu_o i$. Applications: Field of a solenoid. Field due to current sheet. Field in a toroid. Field around and infinite straight wire. Coaxial conductors. Field along axis of a dipole drops off as $1/R^3$ (for example when $B_z = (\mu_o/4\pi)2\mu/R^3$ where $R = \sqrt{r^2 + z^2}$ and r is the radius of a dipole loop).

6. Faraday's Law. $V = \mathcal{E} = -N d\Phi/dt$ where $\Phi = \int \vec{B} \cdot d\vec{A}$. Use Lenz's Law to determine direction of current for induction problems. Voltage across conductors moving in a magnetic field. A.C. generator with a rectangular loop. Homopolar generator. Eddy currents. $\oint \vec{E} \cdot d\vec{s} = -d\Phi/dt$ for electric field induced by changing magnetic field. Betatron principle.

7. Inductance. $V = -L di/dt$. Use $L = N\Phi/i$ to calculate self inductance for a given geometry like a solenoid: $L = \mu_o n^2 A \ell$ (L depends on $N^2$). $U = (1/2)Li^2$. $u = B^2/2\mu_o$. Pressure on solenoid turns $p = B^2/2\mu_o$. mutual inductance: $V_2 = -M_{21} di_1/dt$ and $M_{21} = N_2 \Phi_{21}/i_1$ define Mutual inductance. ($M_{21} \propto N_2 N_1$). Effective inductance for inductors in series and in parallel.

8. Magnetic Fields in Matter. $\oint (\vec{B}/\mu) \cdot d\vec{s} = i$. $\mu = \kappa_m \mu_o$. Ferromagnetism (strong, $\kappa_m \sim 1000$). Paramagnetism (weak, $\kappa_m > 1$). Diamagnetism (very weak, $\kappa_m < 1$). For charge associated with a mass $\mu = eL_{orb}/2m$. Use Ampere's Law to find B in a material with $\kappa_m$ inside a solenoid $B = \mu n i$.

# 3rd PHYSICS 208 REVIEW SHEET (4/17/98)

Reviews Wed. 5-6pm., 1313 Str., Allen; 7-9pm, 2327 Str., Krastev
Last minute questions Thursday 7-8(?)pm 4279 Chamberlin (A. Erwin)

1. Natural Circuit Oscillations. Differential equation for Simple Harmonic Oscillator $\ddot{x} + (k/m)x = 0$. $x = A\,sin(\omega t + \phi)$. $\omega = \sqrt{k/m}$ (from substituting $x = e^{\alpha t}$). Differential equation for L-C circuit. $\ddot{I} + (1/LC)I = 0$. (substitute $I = e^{\alpha t}$). $I = Asin(\omega t + \phi)$. $\omega = \sqrt{1/LC}$. L-R-C differential equation $\ddot{I} + (R/L)\dot{I} + (1/LC)I = 0$. (substitute $I = e^{\alpha t}$). $I = A\,e^{-t/(2L/R)}sin(\omega' t + \phi)$ is a damped oscillation. $\omega' = \sqrt{\omega^2 - (R/2L)^2}$, $\omega \simeq \omega'$ for small R. Give a qualitative description of amplitude vs. frequency for forced oscillations.

2. A.C. Circuits. In charging R-C, voltage lags current. In turning on L-R, voltage leads current. A.C. Ohm's Law: $V_R^{max} = I^{max}R = I^{max}X_R$, $V_C^{max} = I^{max}(1/\omega C) = I^{max}X_C$, $V_L^{max} = I^{max}\omega L = I^{max}X_L$ [Also true if $I^{max}$ is replaced everywhere by $I^{rms} = 0.707I^{max}$]. For instantaneous voltage at any time $V_L = I(\omega L)sin(\omega t + 90°)$, $V_C = I(1/\omega C)sin(\omega t - 90°)$, $V_R = IRsin(\omega t)$. Be able to draw these relations in a phasor diagram. Know how to calculate voltages, currents, and phase angles for R, L, and C hooked in series. $V^{max} = I^{max}Z$, $Z = \sqrt{R^2 + (\omega L - 1/\omega C)^2}$. Z=impedance of various reactance combinations. Phase of voltage across Z relative to current through Z is $\phi = tan^{-1}[(X_L - X_C)/R]$. $P = I_{rms}^2 R = \mathcal{E}_{rms} I_{rms} cos\phi$. Transformers $V_2 = (N_2/N_1)V_1$ and $R_1^{eqiv} = (N_1/N_2)^2 R_2$.

3. Maxwell's Equations. Displacement current $i_d = \epsilon_o \partial\Phi_E/\partial t$. $\epsilon_o$ becomes $\epsilon$ in matter. Source of E can be q or changing B. Source of B can be i or changing E. Write and use the 4 integral versions of Maxwell's equations. Skin effect at high frequencies from Maxwell's equations.

4. Electromagnetic Waves. $E_y = E_m sin(kx - \omega t)$ and $B_z = B_m sin(kx - \omega t)$ constitute a wave moving toward +x. $E_y$ and $B_z$ so described are in phasse

and will satisfy Maxwell's equations. From Maxwell's equations we can show these wave forms will give $E_m = B_m c$ and $c = 1/\sqrt{\epsilon\mu}$. Instantaneous energy per unit volume in a wave is $u = \epsilon_o E_y^2$. $\bar{u} = (1/2)\epsilon_o E_m^2$. Average energy/sec/area is $S = c\epsilon_o E_{rms}^2 = c\bar{u} = I$. Vector direction of a general wave can be expressed with $\vec{S} = (\vec{E}_{rms} X \vec{B}_{rms})/\mu_o$. Average momentum per unit volume of a wave is $\bar{p} = \bar{u}/c$. Radiation pressure if momentum is absorbed is $p = \bar{u} = \epsilon_o E_{rms}^2$ ($= 2\bar{u}$ if completely reflected). Linear polarization $I_y = E_y^2 = (E_m cos\,\theta)^2 = I_m cos^2\theta_y$

5. Reflection and Refraction. Reflection $\theta_1 = \theta_2$. Refraction (Snell's Law) $n_1 sin\,\theta_1 = n_2 sin\,\theta_2$. $n = c/v$ for a transparent material. Chromatic dispersion. Total internal reflection $sin\,\theta_c = n_2/n_1$. Brewster's ploarization angle $\theta_B + \theta_r = 90°$. Construct virtual images for plane mirrors. Spherical mirrors. $1/p + 1/i = 1/f$ where $f = +r/2$ for concave mirrors and $f = -r/2$ for convex mirrors. Ray trace 4 different rays from an object (parallel, through f, through r, to center axis). Real and virtual images. Lateral magnification $m = i/p$. Upright and inverted images.

6. Lenses. Lens makers equation $1/f = (n-1)(1/r_1 - 1/r_2)$. $1/p + 1/i = 1/f$. Negative and positive focal lengths. Use image of one lens as object of another. Ray trace 3 rays (through center, parallel to axis, through f). Magnifier, telescope, microscope, slide projector. Fresnel lens.

7. Light Interference. Young's double slit. Locate angles for minimum and maximum intensity. Phasor description of amplitudes. Reflection from thin films. Rules for phase reversal on reflection at normal incidence. Calculate angles for minimum intensity for diffraction from a single slit. Rayleigh criterion for resolving images of 2 objects. Circular aperture $sin\,\theta = 1.22\lambda/a$ Multiple slits: missing orders, modulation of pattern by slit width, a, and total aperture, Nd. Use of a lens to put screen effectively at infinity. X-ray scattering from crystal planes. $2d sin\,\theta = m\lambda$ ($\theta$ definition here is different for x-rays)

# PHYSICS 208 4TH REVIEW SHEET

**Final Exam: 13-May-1998, 2:45pm, 2650 Humanities**

1. Lorentz Transformations. Know how to transform the four components of a 4-vector from one system to another system moving relative to it with a velocity $v_T$. Know some examples of 4-vectors: $R = (\vec{r}, ict)$, $dR = (d\vec{R}, icdt)$, $V = (\gamma_p \vec{v}_p, ic\gamma_p)$, $Pc = (\vec{p}c, iE)$. Momentum of a particle $\vec{p} = \gamma_p m_o \vec{v}$. Two special cases of Newton's 2nd Law: $F_\perp = \gamma_p m_o a_\perp$ and $F_{||} = \gamma_p^3 m_o a_{||}$. $E = \gamma_p m_o c^2$. Velocity of a particle with momentum p and total energy E, $\beta_p = pc/E$ (from $\beta_p = \beta_T$ and $p' = 0$ in particle rest system). $E^2 = (pc)^2 + (m_o c^2)^2$. Lorentz dialation of time *intervals* and Lorentz contraction of distance *intervals* along the direction of motion. Addition of velocities $\beta_x = (\beta_{x'} + \beta_T)/(1 + \beta_{x'}\beta_T)$. Derive the transverse Doppler shift $f = \gamma_T f'$ and the longitudinal Doppler shift $f = \gamma_T(1 + \beta_T)f'$ from the Lorentz transformations for $E = hf$ of a photon. Be able to compute the "length" of a 4-vector. Know what it means operationally to express mass in units of $MeV/c^2$ and momentum in units of $MeV/c$.

2. Quantum Nature of Light. Black Body Radiation: Wien Displacement $\lambda_{max} = \sigma/T$, Stephen-Boltzman Law $Power = KT^4$ based on $E = hf$ for light. Photoelectric effect $KE = hf - \phi$. Momentum of a massless photon $p = hf/c$ from relativity. Compton effect and wavelength shift in photon-electron collisions by treating light as a relativistic particle. Derive the energy formula for the Bohr atom by assuming angular momentum quantization $mvr = n\hbar$ ($\hbar = h/2\pi$). Quantized orbit radius for the electron. For light emitted by atoms $hf = E_n - E_{n'}$. Estimate x-ray wavelengths for ejected K electrons.

3. Particles as Waves. Momentum of light $p = h/\lambda$. DeBroglie wavelength of a particle $\lambda = h/p$ (or $p = \hbar k$). Condition for maximum reflection of electrons from a crystal (Davisson-Germer experiment). $k = n\pi/d$ for

reflection at normal incidence. Heisenberg Uncertainty Principle for waves and particles $\Delta E \Delta t \gtrsim h$. $\Delta p_x \Delta x \gtrsim h$. $\Delta p_y \Delta y \gtrsim h$. $\Delta p_z \Delta z \gtrsim h$. The idea of Schroedinger's wave equation for a particle in a potential well V(x). Wave amplitude solution $\psi(x)$ is finite near x-position of the particle and zero elsewhere. Probability of finding a particle at x goes as $|\psi(x)|^2$. Particle in an infinitely deep square well of width L has $\psi(x) = A\,sin(kx)$. $k = n\pi/L$ so $\psi$ will vanish at the walls. So $E_n = p^2/2m = \hbar^2 k^2/2m$. $E_n = n^2\pi^2\hbar^2/2mL^2$.

4. Results of Schroedinger's Equation for Coulomb Potential. $E_n = -(13.6\ eV)Z^2/n^2$ for a single electron around a charge +Ze. For orbital angular momentum: $L^2 = \ell(\ell+1)\hbar^2$ [$\ell = 0, 1, 2 ...,$ $|\ell| \leq (n-1)$, so unlike Bohr atom angular momentum can be zero.] and $L_z = m_\ell \hbar$ [$-\ell < m_\ell < \ell$]. Describe the classical picture of L precessing about the z-axis. Spin angular momentum of the electron. $S^2 = s(s+1)\hbar^2$ and $S_z = m_s\hbar$ [s=1/2 and $m_s = \pm 1/2$]. Pauli Exclusion Principle for particles with half integer spin that are "very close" to each other in position. Magnetic energy of electron in a $\vec{B}$ field. $E = -\vec{\mu} \cdot \vec{B} = -\mu_z B_z$. Orbital $\mu_z = m_\ell \mu_B$. Spin $\mu_z = 2m_s\mu_B$. Therefore spin and orbital $\mu_z$ have the same step sizes.

5. Electrical Conduction. Explain why energy levels in a crystal are so close that they form bands. The condition on momentum ($p = \hbar k$) that produces forbidden energy gaps in the bands. Why an electric field cannot produce a net electron drift for electrons in a full band. Draw valence and conduction band pictures and use them to explain the difference between conductors, semiconductors, and insulators. Explain why a semiconductor's resistance decreases with increasing T and a conductor's resistance increases with increasing T. What is the meaning of the Fermi level of electron energy in a crystal.

6. Nuclear Physics. Neutron excess over protons. Nuclear size $R = R_0 A^{1/3}$. Nuclear Bohr magneton definition. Anomalous moments of the proton and

neutron. Spin of a nucleus with even and odd A. Nuclear decays $\alpha$, $\beta$, and $\gamma$. Nuclear reactions and balance of Z and A in the reaction equations. Appearance of spin 1/2, zero mass, neutrino in $\beta$-decay. Binding energy per nucleon curve. Distinguish nuclear fission and fusion with this curve. Two stellar energy sources: Recognize and describe proton and carbon cycles.

7. High Energy Particle Physics. Quark and lepton organization. Weak, electric, and strong forces. Composition of elementary particles. Feyman diagrams to describe interactions. Lepton number and baryon number conservation. Exchange of the Bosons: W, Z, photon, and gluon. Spins and magnetic moments of particles. Size of quarks and leptons. Electroweak theory. Quantum Chromodynamics (QCD) and Quantum Electrodynamics (QED).