Revised 1994

Physics 321

1st Review Sheet

October 5, 1989

1. You should know several physical constants: c, ϵ_o or $1/4\pi\epsilon_o$, μ_o or $\mu_o/4\pi$, and e.

2. Resistors. Ohm's Law. Resistivity. $R = \rho\ell/A$. Ohms "per square". Voltage signs around a D.C. current loop.

3. Kirchhoff's Laws. Sum of voltages around loops. Sum of currrents at a node. Define and count Loops, Meshes, Nodes, Branches and Independent Variables (Unknowns). Be able to count each of these for a given circuit. Use the mesh current technique to get a set of independent equations for independent variables.

4. Simplifying Theorems. Effective series and parallel resistor combinations. Voltage dividers. Current dividers. Meaning of perfect voltage and current sources. Thevenin Theorem. Norton Theorem. Be able to find Thevenin or Norton resistors for not-so-simple D.C. circuits. Be able to calculate the associated Thevenin and Norton generators. Conversion of "T" resistor network to a "Δ" network and vice versa. Superposition Theorem for currents from several sources.

5. Reciprocity Theorem. State the theorem for a 2 port passive (no internal sources), linear system. Express it for an N-port system as set of linear equations for N currents in terms of N voltages. Be able to draw a sketchs to illustrate the meaning of the equations and the theorem. Pay attention to signs of voltages and currents in the sketchs. Use a pi network to illustrate the equivalence of off-diagonal coefficients in the set of equations.

6. Voltmeters, Ammeters, and Ohmmeters. Basic model of a meter as a device described by full scale (F.S.) current and an internal resistance. Define perfect Ammeter and perfect Voltmeter in terms of internal resistance.

Meaning of Ohms-per-Volt or Sensitivity for a basic meter. Be able to calculate the shunt and series resistances needed to convert a basic meter to one with a different full scale current or voltage. Connect voltmeters and ammeters to measure Ohms several ways. Be able to calculate the error in Ohms as measured with given meter characteristics.

7. Internal Resistance. How to measure internal resistance of a device with "half-volt" or "half-amp" method. Impedance matching of internal resistance of a source to a load to deliver maximum power. Use of a passive signal splitter to match internal resistance to several loads.

8. C and L. Definition $C = Q/V$. For parallel plates $C = \epsilon A/d$ where $\epsilon = \kappa\epsilon_o$. $E = (1/2)CV^2 = (1/2)Q^2/C$. Definition $L = N\Phi/I$ or $V = L\,dI/dt = N\,d\Phi/dt$ where $\Phi = BA$. $E = (1/2)LI^2$. For a solenoid $L = \mu_o N^2 A/d$. Effective values for C's and L's hooked in series or parallel. Marx generator. Approximate calculation of C and L for Cu strips on a circuit board.

9. Transient Response for L,R,C Circuits. R-C circuit: Sketch I,Q, and V as a function of time for capacitor charge and discrharge situations. $\tau_c = RC$. Lead and lag of current and voltage. L-R circuit: Sketch I,V, and dI/dt as a function of time. $\tau_L = L/R$. Discharge C in a series L-R-C circuit. Write a differential equation for the loop. Sketch and discuss the 3 types of solutions in terms of the "discriminate" that appears in the solution and the dominance of τ_C or τ_L. Be able to calculate initial ($t = 0$) Q,I, or V and final ($t = \infty$) Q,I, or V in terms of circuit parameters.

10. Alternating Current Circuits. Generalized Ohm's Law. X_R, X_C, and X_L values of reactance. Calculation of impedance Z from X_R, X_C and X_L.

11. Judiciously review homework problems and lab exercises.

Physics 321

2nd Review Sheet

November 9, 1989

1. Same physical constants as last time.

2. *Steady State A.C. in a series-tuned circuit.*

   (a) *Time-Domain:* $V = V_0 \sin \omega t$, $X_C = 1/\omega C$, $X_L = \omega L$, $X_R = R$, and $Z = \sqrt{R^2 + (\omega L - 1/\omega C)^2}$.

   (b) *Frequency Domain:* $V = V_0 e^{j\omega t}$, $X_C = 1/j\omega C$, $X_L = j\omega L$, and $Z = R + j\omega L - 1/j\omega C$. Definition of Q as $\Delta\omega/\omega = 1/Q$ or $Q = \frac{1}{2\pi}$. Ratio of stored energy to average dissipated energy per cycle. ($Q = \omega_0 L/R$), $\omega_0 = 1/\sqrt{LC}$. Phase angle φ between I and the V across any element or combination of elements. Average Power $= V_{\text{rms}} I_{\text{rms}} \cos\varphi$. $\cos\varphi = Re(Z)/|Z|$.

3. *Filters for A.C. signals.* Frequency domain analysis of R-L, R-C, and L-C attenuators. Find ω_C (cut-off, corner, or critical frequency) for each filter and calculate dB per octave or dB per decade at limiting frequencies. Explain R-C (L-R) "integrators" and R-C (L-R) "differentiators".

4. *Transformers—Magnetic Circuits.* Ideal transformer. $V_{\text{out}}/V_{\text{in}} = N_s/N_p$. $Z_{\text{in}} = Z_L(N_p/N_s)^2$. A non-ideal transformer model with leakage (*e.g.*, Problem 4.23). Magnetic Ohm's Law $NI = \Phi R$.

5. *Special A.C. Circuits.* A.C. bridge, Wien-Bridge, Twin-Tee, Parallel Tuned R-L-C circuit, and frequency compensated voltage divider.

6. *Fourier Series.* "Orthogonality" conditions on $\sin(n\omega t)$, $\cos(n\omega t)$ or on $e^{jn\omega t}$, $e^{-jn\omega t}$. $a_n = (2/T)\int_{-T/2}^{T/2} V(t)\cos n\omega t\, dt$, *etc.*
   Examples of square wave voltage expansion and full-wave, rectified A.C. voltage expansion. The use of even-function, odd-function symmetry to eliminate calculation of some Fourier coefficients. *Complex* ($e^{jn\omega t}$) Fourier

expansion and alternative interpretation of negative n as negative frequency. How to use complex impendances with each frequency term to solve for circuit response to an expanded wave (*e.g.*, Problem 5.7).

7. *Fourier Transform.* For use with waveforms of finite extent (or infinite period T) $\tilde{V}(\omega) = (1/\sqrt{2\pi}) \int_{-\infty}^{\infty} V(t)e^{-j\omega t}\,dt$ and the inverse $V(t) = (1/\sqrt{2\pi}) \int_{-\infty}^{\infty} \tilde{V}(\omega)e^{j\omega t}\,d\omega$. Interpretation of $|\tilde{V}(\omega)|^2$ as the frequency power spectrum. Calculate the frequency power spectrum of an oscillation damped in time. Show that the product of its "time width" (Δt) and its "frequency width" $\Delta\omega$ is a constant.

8. *Transmission Lines* with 2 conduunctors (not wave guides which have 1 conductor) Phase velocity $v = \lambda f = \sqrt{1/L'C'}$. Characteristic Impedence $Z_0 = \sqrt{L'/C'}$ is purely resistive for an infinitely long line. $v = \sqrt{1/\epsilon\mu}$ for coaxial cable where $\epsilon = \kappa\epsilon_0$, $\mu = \mu_0$. Impendance refelcted back to the source from a load at the end of a half wavelength line and at the end of a quarter wavelength line.

9. *Diodes.* Discuss Vacuum diode only as a constant current source above a few volts. Use Junction diodes for all other discussion. Know exponential form for I vs V. Derive dynamic resistance (transresistance) of a junction: $r_{tr} = 25/I(mA)$. Typical forward drop for Si(0.6 V) and Ge(0.25 V). Define Peak-Inverse-Volts, maximum surge-current, and back-current. Describe Zener breakdown and its use as a nearly temperature independent voltage regulator.

10. *Clips and Clamps.* Sketch circuits that will clip a voltage wave form at a predetermined voltage level (plus or minus). Sketch a circuit that will clamp a periodic voltage wave form at a predetermined D.C. level.

11. *Power Supplies.* Full-wave center-tap, half-wave, full-wave bridge rectifiers. What PIV must a diode sustain in each of these? Define "ripple" fraction and "regulation". Calculate ripple fraction for C-input, R_L-C filter on a half wave or full wave rectifier. Sketch a choke-input, L-C filter and describe

its effect on surge current. For a given transformer voltage, explain how to predict D.C. output of a power supply for full-wave or half wave rectification with either C-input or L-input filters. Sketch a voltage multiplying rectifier (charge pump).

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3rd Review Sheet

December 14, 1989

1. Bipolar Transistor. Typical characteristic curves for I_c vs. V_{ce} plotted for different values of I_b. Define α and β (h_{fe}). NPN and PNP types. Calculate D.C. base-bias for a pull-up resistor and a voltage divider. Find the operating point with a load line intersecting characteristic curves. Draw the D.C. circuit and the A.C. equivalent circuit for an NPN amplifier and analyze it with the T-equivalent transistor. Derive voltage gain and input and output impedance for the collector or emitter ouput connections. (See handout.) $r_{tr} \simeq 26/I_E(mA)$. Effect on gain of by passing the emitter resistor in a voltage amplifier. Uses of an emitter follower. Darlington pair.

2. Operational Amplifiers. Characteristics of a perfect Op-Amp. Negative feedback and its ability to make $v_+ - v_- \simeq 0$ at the input. General effects of negative feedback on the input and output resistances. Derive the function of several common Op-Amp applications (see handout and homework).

3. Positive Feedback. One example only, the Op-Amp Relaxation Oscillator. Draw the circuit. Describe operation and voltages at input and output. Derive the oscillation period.

4. Digital Logic. Describe AND, OR, NAND, and NOR operation. Know standard circuit symbols for these. Boolean algebra and simple identities. Be able to go from circuits to algebra and to truth tables, starting with any one of these. State both forms of DeMorgan's theorem with algebra and with circuits. Construct an XOR. Binary numbers. Addition and subtraction with 2's complements. Octal and Hexadecimal numbers.

5. Integrated Circuits. Draw and describe operation of a Flip-Flop, a Set-Reset F-F, and a Master-Slave J-K F-F. Truth table for M-S J-K F-F. Wire J-K M-S F-F's to make a binary counter and a shift register.

6. <u>Thermal Noise</u>. $v_{rms} = \sqrt{4R\,kT\,\Delta f}$ Be able to calculate thermal noise voltage for simple situations.

7. <u>Television</u>. Qualitative description of how it works.