PHYS 202 OUTLINE FOR PART I
ELECTRICITY

Electric Forces and Electric Fields

A. Electric force (vector) S-1,2,3

1. four fundamental forces: gravity, E&M, two nuclear
2. Coulomb's Law: $F = kq_1q_2/r^2$ (similar to $F = Gm_1m_2/r^2$)
3. Two kinds of charge (to explain attraction and repulsion) versus one kind of mass (attraction only)
3. protons and electrons: charge (q) and mass (m)
    a) proton: $q = +e = +1.6 \times 10^{-19}$ C; $m = 1.67 \times 10^{-27}$ kg
    b) electron: $q = -e = -1.6 \times 10^{-19}$ C; $m = 9.11 \times 10^{-31}$ kg
4. insulators and conductors

B. Electric field S-4

1. definition: $\mathbf{E} \equiv \mathbf{F}_{(\text{on } q_t)}/q_t$ (a vector)
2. units: Nt/Coul (or Volt/meter; see below)
3. for point charge, **magnitude**: $E = kq/r^2$, **direction**: points away from +q, toward -q
4. for several charges: add as vectors (express in POLAR, but add in RECTANGULAR)

Supplementary Problems (S-):

1. At a particular instant a particle of mass $m_A = 5$ mg and charge $q_A = 5$ μCoul is located at the origin. A second particle of mass $m_B = 2$ mg and charge of $q_B = -6$ μCoul is located at that same instant at a position (-5 m, +3 m) relative to the origin. a) What is the force on q_A due to the presence of q_B ? b) Is the magnitude of the force on q_B due to the presence of q_A the same, greater or smaller than the magnitude of the force on q_A due to the presence of q_B ? c) Assuming the two charges have no other forces on them, what is the magnitude of the resulting acceleration of particle A due to the electrical interaction with particle B? d) Is the acceleration of particle B due to the presence of particle A the same, greater or smaller than the magnitude of the acceleration of particle A?

2. In the hydrogen atom the electron orbits the proton at a distance of 5×10^{-11} meters. a) What is the electric force on the electron due to the proton? b) What is the velocity of the electron in its orbit about the proton? [HINT: use $\Sigma\mathbf{F}=m\mathbf{a}$ and recall for circular motion that $a=v^2/r$.]

3. a) What is the magnitude of the gravitational force between the proton and the electron when they are separated by 1 nm? b) What is the electrical force between the proton and the electron when they are separated by 1 nm? c) Which force is the stronger? d) How many significant figures would have to be used before the weaker force would alter the net force from being equal to the stronger force? [EXAMPLE: if $F_1=1.000$ Nt and $F_2=0.01$ Nt, then $F_{net}=F_1$ to 2 significant figures (1.0), but the third significant figure would be changed (1.01 instead of 1.00).]

4. Consider two charges: q_A has a charge of 5 nCoul and is located at (5 m, 3 m); q_B has a charge of -4 nCoul and is located at (7 m, -2 m). a) What is the electric field at the origin due to q_A alone? b) What is the electric field at the origin due to BOTH charges?

Answers to Supplementary Problems:

1. a) 7.94×10^{-3} Nt; b) same; c) 1,588 m/s²; d) acceleration of B is larger.
2. a) 9.2×10^{-8} Nt; b) 2.2×10^{6} m/s.
3. a) 1.01×10^{-49} Nt; b) 2.3×10^{-10} Nt; c) electrical; d) 39.
4. a) E = 1.32 Nt/Coul at 211°; b) E = .99 Nt/Coul at 241°

Electrical Energy and Capacitance

A. Electric potential (Voltage, EMF) S-5,6,7

1. definition: $V \equiv PE_{(of\ q_t)}/q_t$ (a scalar)
2. units: Volt = Joule/Coul
3. for point charge, V = kq/r (positive for +q, negative for -q)
4. for several charges, add as scalars
5. use in conservation of energy: $PE_{el} = q\,V$
6. related to field: $E_x = -\Delta V/\Delta x$; $E_y = -\Delta V/\Delta y$

B. Electron beams S-8

1. conservation of energy
2. x-ray tubes
3. Cathode Ray Tubes (CRT): T.V.'s, monitors, oscilloscopes

C. Capacitance S-9

1. definition: $C \equiv Q/V$ [stores charge and hence energy]
2. units: Farad = Coul/Volt
3. geometry: for parallel plate, $C = K\,A\,/\,(4\,\pi\,k\,d)$
   [K is dielectric constant, A is area, d is distance, k is Coulomb's constant]
4. energy stored: Energy = $\frac{1}{2}\,Q\,V = \frac{1}{2}\,C\,V^2$

Supplementary Problems (S-):

5. Consider two charges (same as for problem S-4): q_A has a charge of 5 nCoul and is located at (5 m, 3 m); q_B has a charge of -4 nCoul and is located at (7 m, -2 m). a) What is the electric potential at the origin due to q_A alone? b) What is the electric potential at the origin due to BOTH charges?

6. a) What change in potential energy does a +6 μC charge experience in moving from a position where the potential is 60 volts to one where it is 35 volts? Express your answer in Joules and in eV. b) If the charge has a mass of 2 mg, and the charge was initially at rest, and if all the potential energy change went into changing the particles kinetic energy, how fast would the particle be going when it reached the 35 volt position?

7. a) Through how many volts will an electron have to be accelerated if it is to reach 1 million miles/hr if it starts from rest? b) Should the electron fall through twice the voltage difference to reach twice the speed? c) Through how many volts will a proton have to be accelerated if it is to reach 1 million miles/hr?

8. Be able to describe how a CRT works.

9. a) If a 2 μF capacitor is charged up with a 12 volt battery, how much energy is stored in the capacitor? b) How much charge is stored on the capacitor? Now suppose that half the charge is drained off the capacitor. c) Will the voltage also be decreased by a factor of 2 (that is, ½) - if not, by what factor is it changed? d) Will the energy stored also be decreased by a factor of 2 - if not, by what factor is it changed?

Answers to Supplementary Problems:

5. a) +7.72 volts; b) +2.77 volts.
6. a) decrease of 1.5×10^{-4} Joules = 9.37×10^{14} eV; b) 12.25 m/sec = 27.4 mph.
7. a) 0.57 volts; b) no, it will need to fall through 4 times the voltage difference; c) 1,040 volts.
9. a) 144 mJ or .144 μJ; b) 24 μC; c) Yes; d) No, decreased by a factor of 2^2 or 4 (that is, by ¼).

Current and Resistance

A. Current

1. definition: $I \equiv \Delta q / \Delta t$
2. units: Ampere = Coul/sec

B. Voltage, current, and resistance S-10,11

1. Ohm's Law: $V = I R$ (where Ω = Ohm = Volt/Amp
2. RESISTANCE: $R = \rho L / A$ where ρ is resistivity
3. POWER: $P = I V = I^2R = V^2/R$ (W = Watt = Volt*Amp)

Supplementary Problems (S-):

10. A 60 Watt light bulb is designed to work with a 110 volt power supply. a) What is the current through the light bulb? b) What is the resistance of the light bulb? c) Does a 100 Watt light bulb have a lower or higher resistance than the 60 Watt bulb?

11. From the Capacitance and Dielectrics part D, energy stored in a capacitor is $PE = \frac{1}{2}QV$. From the Current & Resistance part C, $PE = QV$. Explain why there is a ½ in the one but not the other equation.

Answers to Supplementary Problems:

10. a) 0.55 Amps; b) 200 Ω; c) less.

Direct Current Circuits

A. Resistive circuits S-12

1. series: $R_{total} = R_1 + R_2 + \ldots = \Sigma R_i$ (more length - harder - bigger R)
2. parallel: $(1/R_{total}) = (1/R_1) + (1/R_2) + \ldots = \Sigma (1/R_i)$ (more area - easier - less R)

Supplementary Problems (S-):

12. You are given three resistors: $3\,\Omega$, $6\,\Omega$, and $12\,\Omega$.
a) Draw a diagram showing how to connect the resistors so that you get the smallest effective resistance, and calculate that effective resistance.
b) Is your connection above purely parallel, purely series, or a combination?
c) Draw a second diagram showing how to connect the resistors so that you get the largest effective resistance, and calculate that effective resistance.
d) Draw a third diagram showing how to connect the resistors so that you get some value between $6\,\Omega$ and $12\,\Omega$ for the effective resistance, and calculate that effective resistance.

Answers to Supplementary Problems:

12. a) $R_{eff} = 1.714\,\Omega$; c) $R_{eff} = 21\,\Omega$.