## PRACTICE PROBLEMS II

This is the problem practice set for PHY102 FINAL EXAM. This problem set covers the topics after the midterm. It should be used **together with the midterm practice problems** in order to prepare for the final exam. *The final exam will cover all topics of this semester starting with the basic properties of electric charges and ending with the relativity.* There are also two problems on the set from before the midterm (1 and 4), which no one was able to do properly on the midterm but still you should most definitely know if you want to do well on the final exam.

This problem set does not mean that the problems on the final exam will be the same. What it means is that, if you can solve these problems by yourself, you are likely to be able to answer all of the practical questions on the exam.

The final exam will consist of 5 to 10 questions, both practical and theoretical. Any topic, example, or proof from the lectures can appear on the theoretical part. Since the material given in the class did not correspond strictly to your textbook, I strongly advise you to use class notes for your preparations for the exam.

According to the exam rules, you will be allowed to bring and use in the exam two two-sided A4 papers of *hand-written notes*. **No photocopies of any kind will be allowed during the exam**. No books or notebooks will be allowed. You can bring a separate calculator, but you will not be able to use the calculator in your cell phone. It is also advised that you bring a dictionary to the exam.

**Topics covered in final exam:**

1. Fundamental properties of electric charges
2. Electric force and Coulomb's law
3. Electric field of a point charge and system of point charges
4. Electric force from electric field
5. Flux of a vector field, area vector
6. Gauss' law and applications of Gauss' law
7. Electric field of electric dipole, infinite plane, infinite straight wire, and uniformly charged sphere
8. Electric properties of conductors, redistribution of charges and electric field inside conductors in response to external electric field in static conditions
9. Electric properties of dielectrics, electric field in dielectrics
10. Polarization density vector and the polarization electric field
11. Electric potential and work of electric field on moving charge
12. Electric potential of a point charge and a system of point charges, electric energy of a system of charges
13. Electric potential of electric dipole, infinite straight wire, and uniformly charged sphere
14. Electric potential in conductors, capacitance, relationship between charge, potential and capacitance
15. Capacitors and their properties, addition of capacitances in series and parallel capacitors
16. Capacitance of parallel plate capacitor, cylindrical capacitor, and spherical capacitor
17. Fundamental properties of electric currents, relationship between current and electric field in conductors, resistivity and conductivity
18. Ohm's law for electric currents, resistance, addition of resistance in series and parallel resistors
19. Kirchhoff's rules, calculating currents and voltages in multi-loop DC circuits

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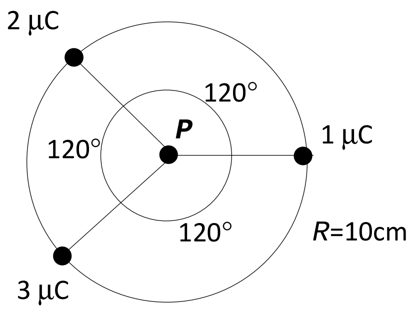
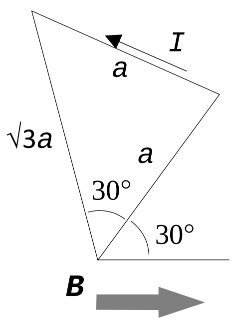
20. Magnetic field of moving charges
21. Lorentz force, motion of electrical charges in magnetic field
22. Biot-Savart law, calculation of magnetic field from currents of different forms
23. Magnetic force on electric current
24. Magnetic field of magnetic dipole (<u>including the derivation of the formula</u>)
25. Ampere's law, applications of Ampere's law
26. Magnetic field of an infinite straight current, magnetic field of a solenoid
27. Properties of magnetic materials (diamagnetic, paramagnetic, ferromagnetic)

28. Magnetization and magnetization field
29. Properties of ferromagnetic materials and hysteresis curve
30. Faraday's law, Lentz rule
31. Self-inductance in a solenoid, inductance of a solenoid, mutual inductance in solenoids
32. Properties of RC, RL and LC circuits, oscillations in LC circuits
33. Energy stored in capacitor and solenoid
34. Energy density of electric and magnetic fields
35. Properties of resistances, capacitances, and inductances in AC circuits, resistance, reactance, and phase shifts between voltage and current
36. Phasor diagrams for RLC circuits, impedance and phase shift for RLC AC circuits, relationship between voltage and current in RLC AC circuits
37. Resonance in RLC AC circuits
38. Maxwell equations for electro-magnetic fields, displacement current
39. Maxwell equations and electro-magnetic waves, properties of electro-magnetic waves
40. Maxwell equations and relativity, Lorentz transformation and applying Lorentz transformation, time dilation and length contraction

**Problem 1:** For system of charges shown in figure below calculate
(a) Electric field at point *P*
(b) Electric potential at point *P*
(c) Force on charge $Q$=2 μC placed at point *P*
(d) Energy released if this system were to break up and all charges were to fly away to infinity



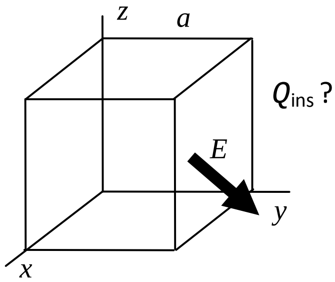

**Problem 2:** Calculate the total magnetic force applied to the triangular current placed in magnetic field as shown below. $I$=1A, $B$=0.1T, $a$=10cm.



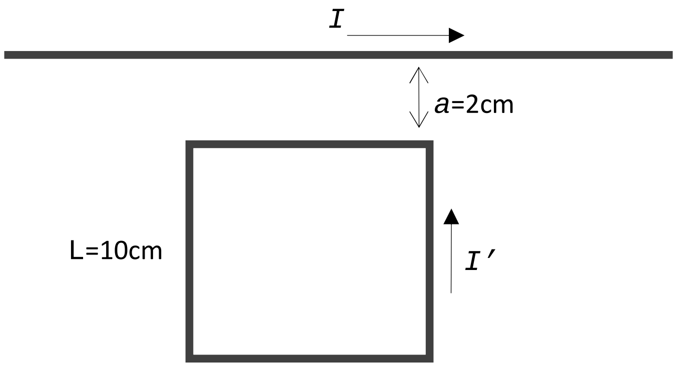

**Problem 3:** Consider two observers, one stationary and one moving with relativistic speed $V$≈c such that $1 - V^2/c^2 = 1/4$. Consider two events *A* and *B* that for the stationary observer have occurred at positions and times $x_A$=3·10$^8$ m and $t_A$=5s and $x_B$=–6·10$^8$m and $t_B$=3s.
(a) Find the positions and times of these two events for the moving observer
(b) Find the time difference between the two events for the moving observer
(c) Find the distance between the two events for the moving observer

**Problem 4:** In order to measure the size of an object of length $L$ one needs to measure *simultaneously* ($\Delta t' = 0$) the distance $\Delta x^{'}$ between the two ends of the object *A* and *B*. Consider two such events *A* and *B* with $\Delta t' = 0$ and $\Delta x^{'} \neq 0$ for an observer moving with speed *V*. (a) Show using the Lorentz transformation that in order to have $\Delta x = L$ for a stationary observer (the true length of the object) one must have $\Delta x^{'} = \gamma \cdot L < L$, that is the object is shorter for moving observer. (b) What is the time difference between "simultaneous" events *A* and *B* as seen by stationary observer?

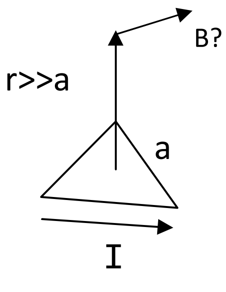
**Problem 5:** An electric field given by $\vec{E}(x, y, z) = (4x, 2y, -2z)$ V/m. What is the charge $Q_{\text{ins}}$ contained inside the cube of edge length *a*=1 m shown below?




**Problem 6:** An infinite straight wire and a square wire-loop are placed nearby, as shown below. The current in the wire is $I$=30A and the current in the loop is $I'$=10A. (a) What is the total force acting on the loop from current $I$? (b) What is the total torque acting on the loop from current $I$?



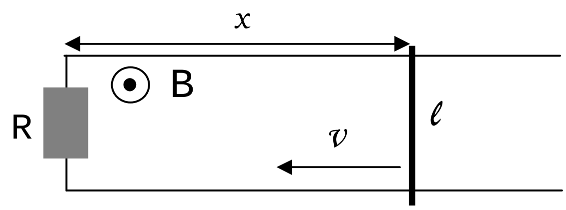

**Problem 7:** Consider an equilateral triangular current as shown below. Calculate magnetic field *B* at distance *r*>>*a* along the line running through the center of the triangle in direction perpendicular to the plane of the current. (Note: at very large distances *r*>>*a* each side of the triangle can be treated as one elementary current-length element $I\Delta L$ in the Biot-Savart law.)




**Problem 8:** For a certain material magnetic permittivity $\mu$=10. If this material is placed in external magnetic field $B=10^{-3}$ Tesla,

(a) What is the magnetic field inside the material?
(b) What is the magnetization inside the material?
(c) What kind of material is that (diamagnetic, paramagnetic, ferromagnetic)?

**Problem 9:** A conducting bar of length $\ell$ is moving in a uniform magnetic field *B* with velocity *v* along a pair of conducting wires, as shown below. If the resistance in this circuit is *R*, (a) find the current induced in the circuit; (b) what is the direction of the current?

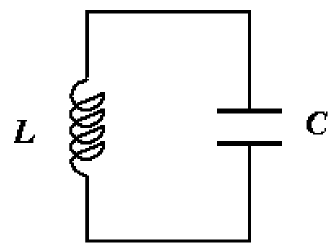



**Problem 10:** In a LC circuit made of a capacitor *C*=1μF and inductance *L*=0.1mH the oscillating current could be described by the formula $I(t) = I_0 \sin(\omega t)$ with $I_0$=0.1 A and ω=100 KHz.

(a) What is the maximal energy stored inside the capacitor and inside the inductance during these oscillations?

(b) If the volume of the capacitor and the inductance is 1 $cm^3$, what is the largest electric and magnetic energy density inside the capacitor and the inductance? What is the largest strengths of electric and magnetic field inside the capacitor and the inductance during these oscillations?

(c) What is the maximal charge on the capacitor and the maximal current through the inductance during these oscillations?




**Problem 11:** An 10 Volt AC source with frequency ω is connected in a series with resistor *R*=50 Ω and inductance *L*=1 H.

(a) Draw the *circuit diagram* for this circuit.

(b) Draw the *phasor diagram* for AC voltage in this circuit.

(c) At what frequency ω the voltages $\Delta V_L = \Delta V_R$?

(d) At that frequency, what is the total impedance *Z*, current $I$ and phase shift $\phi$ in this circuit?

**Problem 12:** Consider a parallel plate capacitor of area *A*=100 $cm^2$ and distance between the plates *d*=1cm. If the electric field between the plates of the capacitor *E*=$10^5$ V/m, what is the energy stored in the capacitor?