# PHYS 102 – General Physics-II, Final

Duration: 120 minutes May 26, 2010

**NAME**:............................................................. **Section**:.....................

| Q.1 (25) | Q.2 (25) | Q.3 (25) | Q.4 (25) | Total (100) |
|---|---|---|---|---|
| | | | | |

**You must sign the Honor Code for your exam to be graded:**

*"I pledge, on my Honor, not to lie, cheat, or steal in either my academic or personal life. I understand that such acts violate the Honor Code and undermine the community of trust of which we are all stewards."*

| I agree to abide by this Honor Code during this exam. | **Signature:** |
|---|---|

**Don't forget to sign!**

**Present your work in a legible and organized format, otherwise you may lose significant portion of your credit even if your solution is correct!**

Magnesia (near Aydın), Plato's Ideal City and from where "magnetism" word originates.

Solutions will be posted to → http://www.fen.bilkent.edu.tr/~phys102

## Some expressions from the Textbook which may or may NOT be useful for this exam

**(However, you are supposed to know what each symbol means)**

**Coulomb's Law & Electric Field:**

| | | | |
|---|---|---|---|
| $F = \frac{1}{4\pi\varepsilon_0}\frac{\lvert q_1 q_2\rvert}{r^2}$ | $\vec{E} = \frac{\vec{F}_0}{q_0}$ | $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$ | (For a point charge, $q$) |

**Torque and Potential Energy of an Electric Dipole in an Electric Field:**

| | |
|---|---|
| $\vec{\tau} = \vec{p}\times\vec{E}$ | $U = -\vec{p}\cdot\vec{E}$ |

| | |
|---|---|
| **Gauss's Law:** $\Phi_E = \oint \vec{E}\cdot d\vec{A} = \frac{Q_{\text{encl}}}{\varepsilon_0}$ | $E_\perp = \frac{\sigma}{\varepsilon_0}$ (Perpendicular component of the electric field at the surface of a conductor) |

**Electric Potential & Potential Energy:**

| | | |
|---|---|---|
| $V = \frac{U}{q_0}$ | $V = \frac{1}{4\pi\varepsilon_0}\sum_i \frac{q_i}{r_i}$ (Collection of point charges) | $U = \frac{q_0}{4\pi\varepsilon_0}\sum_i \frac{q_i}{r_i}$ ($q_0$ with other point charges) |

| | | |
|---|---|---|
| $V = \frac{1}{4\pi\varepsilon_0}\int \frac{dq}{r}$ (For a charge distribution) | $V_a - V_b = \int_a^b \vec{E}\cdot d\vec{l}$ | $\vec{E} = -\left(\hat{i}\frac{\partial V}{\partial x} + \hat{j}\frac{\partial V}{\partial y} + \hat{k}\frac{\partial V}{\partial z}\right)$ |

**Capacitance:**

| | | | |
|---|---|---|---|
| $C = \frac{Q}{V_{ab}}$ | $C = \varepsilon_0\frac{A}{d}$ (Parallel plate) | $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$ (series) | $C_{eq} = C_1 + C_2 + \cdots$ (parallel) |

**Energy in a Capacitor:**

| | |
|---|---|
| $U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$ | $u = \frac{1}{2}\varepsilon_0 E^2$ (Stored energy density) |

**Capacitors with Dielectrics:**

| | | | |
|---|---|---|---|
| $C = KC_0$ | $C = K\varepsilon_0\frac{A}{d} = \varepsilon\frac{A}{d}$ (Parallel plate) | $u = \frac{1}{2}K\varepsilon_0 E^2 = \frac{1}{2}\varepsilon E^2$ | $\oint K\vec{E}\cdot d\vec{A} = \frac{Q_{\text{encl-free}}}{\varepsilon_0}$ |

| | |
|---|---|
| **Current and current density:** $I = \frac{dQ}{dt} = n\lvert q\rvert \upsilon_d A, \quad \vec{J} = nq\vec{\upsilon}_d$ | **Resistivity and Ohm's Law:** $\rho = \frac{E}{J}, \quad V = IR$ |

| | |
|---|---|
| **Kirchhoff's Rules:** $\sum I = 0$ (junction rule), $\sum V = 0$ (loop rule) | **Power:** $P = V_{ab}I$ |

**Equivalent Resistance:**

| | |
|---|---|
| $R_{eq} = R_1 + R_2 + \cdots + R_n$ (in series) | $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$ (in parallel) |

**Simple R-C Circuit:**

| Charging: | Discharging: |
|---|---|
| $q(t) = C\mathcal{E}\left(1-e^{-t/(RC)}\right) = Q_f\left(1-e^{-t/(RC)}\right)$ <br> $i(t) = \frac{dq}{dt} = \frac{\mathcal{E}}{R}e^{-t/(RC)} = I_0 e^{-t/(RC)}$ | $q(t) = Q_0 e^{-t/(RC)}$ <br> $i(t) = \frac{dq}{dt} = -\frac{Q_0}{RC}e^{-t/(RC)}$ |

**Magnetic Forces:**

| | |
|---|---|
| $\vec{F}_m = q\vec{\upsilon}\times\vec{B}$ (on a point charge *q*) | $d\vec{F}_m = I\ d\vec{l}\times\vec{B}$ (on a current-carrying segment $d\vec{l}$ ) |

| Magnetic Flux: | Magnetic Torque and Potential Energy: |
|---|---|
| $\Phi_B = \int \vec{B}\cdot d\vec{A}, \quad \oint \vec{B}\cdot d\vec{A} = 0$ (for a closed surface) | $\vec{\tau} = \vec{\mu}\times\vec{B}, \quad \vec{\mu} = I\vec{A}, \quad U = -\vec{\mu}\cdot\vec{B}$ |

| Hall Effect: | Cyclotron Radius: |
|---|---|
| $nq = \frac{-J_x B_y}{E_z}$ | $R = \frac{m\upsilon}{\lvert q\rvert B}$ |

| Magnetic Field of a moving charge *q*: | Magnetic Field of a Current-Carrying Segment: |
|---|---|
| $\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{\upsilon}\times\hat{r}}{r^2}$ | $d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\hat{r}}{r^2}$ |

| Magnetic Field of a Long Straight Wire: | Magnetic Force Between Two Parallel Wires: |
|---|---|
| $B = \frac{\mu_0 I}{2\pi r}$ | $\frac{F}{L} = \frac{\mu_0 II'}{2\pi r}$ |

| Axial Magnetic Field of a Current Loop of Radius *a*: | Ampere's Law: |
|---|---|
| $B_x = \frac{\mu_0 NI}{2a}$ (at the center of *N* circular loops) | $\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{encl}$ |

**Faraday's Law, Motional emf, Induced Electric Fields:**

| | | |
|---|---|---|
| $\mathcal{E} = -\frac{d\Phi_B}{dt}$ | $\mathcal{E} = \upsilon BL, \quad \mathcal{E} = \oint\left(\vec{\upsilon}\times\vec{B}\right)\cdot d\vec{l}$ | $\oint \vec{E}\cdot d\vec{l} = -\frac{d\Phi_B}{dt}$ |

**Displacement Current & Maxwell's Equations:**

| | | |
|---|---|---|
| $i_D = \varepsilon\frac{d\Phi_E}{dt}$ | $\oint \vec{B}\cdot d\vec{A} = 0$ | $\oint \vec{B}\cdot d\vec{l} = \mu_0\left(i_C + \varepsilon_0\frac{d\Phi_E}{dt}\right)_{encl}$ |

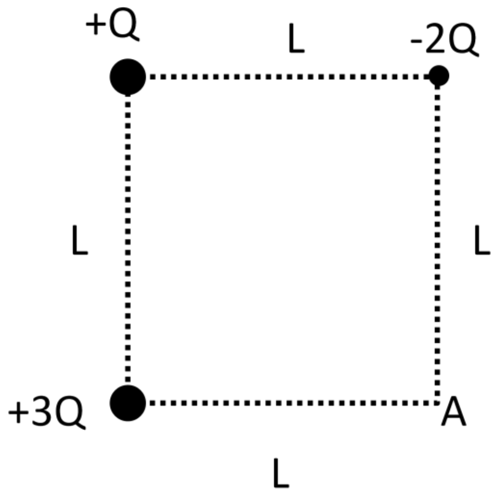
**Inductance:**

| | | | |
|---|---|---|---|
| $\mathcal{E} = -L\frac{di}{dt},\ L = \frac{N\Phi_B}{i}$ | $U = \frac{1}{2}LI^2,\ u = \frac{B^2}{2\mu}$ | $\tau = \frac{L}{R}$ | $\omega = \sqrt{\frac{1}{LC}}$ |

**Electromagnetic Waves:**

| | | |
|---|---|---|
| $E = cB,\ c = \frac{1}{\sqrt{\varepsilon_0\mu_0}}$ | $\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B}$ | $I = S_{av} = \frac{E_{\max}B_{\max}}{2\mu_0}$ |

**Q.1 *(25 points)* Electrostatics**




Three point charges are arranged at the corners of a square of side **L** shown in the figure.

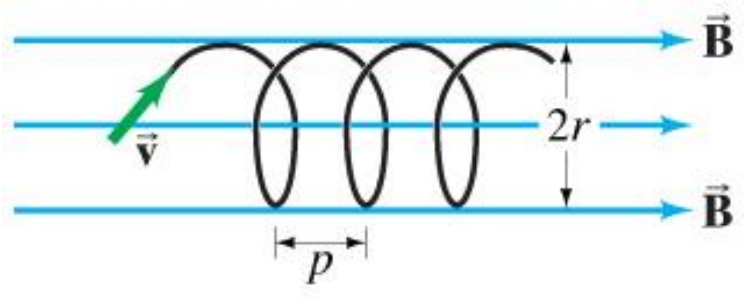
a) What is the potential at the forth corner (point A)?

b) What is the electric field at point A?

•

**Q.2** ***(25 points)*** **Magnetic Force**

An electron enters a uniform magnetic field B=0.5 T at a 45$^{o}$ angle to $\vec{B}$ . Determine the radius **r** and pitch **p** (distance between the loops) of the electron`s helical path assuming its speed is 3.0x10$^{6}$ m/s. (mass of electron $m_e$ =9.11x10$^{-31}$ kg and charge of electron q=1.6x10$^{-19}$C)

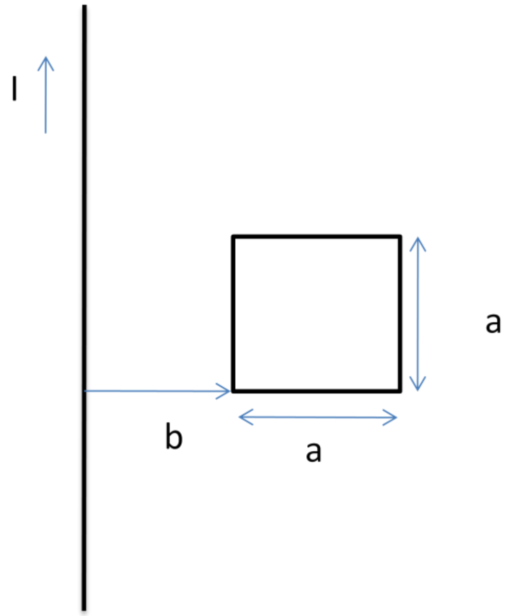



**Put answer in this box**

*r* =

*p* =

## Q.3 *(25 points)* Induction




**a)** Determine the magnetic flux through a square loop of side ***a*** (shown in the figure) if one side is parallel to and at a distance ***b*** from a long straight wire that carries a current ***I***. **b)** Determine the mutual inductance between the wire and the loop. **c)** If the loop is pulled away from the wire at a speed ***v***, what emf is induced in it? **d)** Find the direction and the magnitude of the induced current if the resistance of the loop is ***R*.**

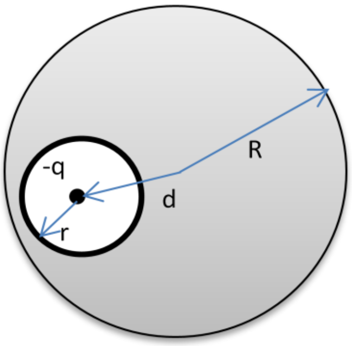
**Put answers in these boxes**

| | | | |
|---|---|---|---|
| $\Phi=$ | $M =$ | $V_{emf}=$ | $I_{ind} =$ |

**Q.4** ***(25 points)*** **Conceptual Questions**

Answer the following questions **in** the box for each part. To claim any credit for your discussions, **base your reasoning on physics (laws).**

**(a)** ***(6 points)*** Consider the charging of a capacitor in an R-C circuit. How does the current pass from one plate to the other plate of the capacitor even though the region between the plates of the capacitor is filled with an insulating (i.e., non-conducting) material?




**(b)** ***(7 points)*** A solid conductor carries a net positive charge Q. There is a hollow cavity within the conductor. At the center of the cavity there is a negative point charge –q. a) What is the charge on the outer surface and the inner surface of the conductor. b) Calculate the electric field at the center of the conductor.

**(c)** ***(6 points)*** A parallel-plate capacitor carries charge Q and is then disconnected from the battery. The two plates are initially separated by a distance d. Suppose the plates are pulled apart until the separation is 2d. How has the energy stored in the capacitor?

**(d)** ***(6 points)*** If the magnetic field vector of a plane wave is $\hat{j}B_0$ and its electric field is $\hat{k}E_0$, (both $B_0$, $E_0$ are positive) determine the direction of propagation of this wave?