KOÇ UNIVERSITY
College of Sciences
PHYS 102 General Physics 2
Spring Semester 2010
Midterm Exam 1
March 23, 2010 Tuesday, 18:30-20:00

Please read.

• Count to make sure that there are 5 pages in this question booklet
• Check your name, number, on front page, and student ID on each page.
• This examination is conducted with closed books and notes.
• Put all your personal belongings underneath your seat and make sure that pages of books or notebooks are not open.
• Absolutely no talking or exchanging anything (like rulers, erasers) during the exam.
• You must show all your work to get credit; you will not be given any points unless you show the details of your work (this applies even if your final answer is correct).
• Write neatly and clearly; unreadable answers will not be given any credit.
• If you need more writing space, use the backs of the question pages and put down the appropriate pointer marks.
• Make sure that you include units in your results.
• Make sure that you label the axis and have units in your plots.
• You are not allowed to use calculators during this exam.
• Turn off your mobile phones, and put away.
• You are not allowed to leave the class during the first 15 minutes, and last 15 minutes.

Integrals: \[
\int \frac{dy}{\sqrt{y^2 + a^2}} = \ln \left( y + \sqrt{y^2 + a^2} \right)
\]
\[
\int \frac{ydy}{(y^2 + a^2)^{3/2}} = -\frac{1}{\sqrt{y^2 + a^2}}
\]

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1-(25 Points) Three point charges with magnitudes $Q_1 = q$, $Q_2 = -2q$, $Q_3 = 2q$ are located at distance $a$ away from the origin along the positive $x$-, $y$- and $z$-axes, respectively.

a) Find the electric potential at the origin in terms of $k$, $q$ and $a$.

b) Write the electric field at the origin using the unit vectors $\hat{i}$, $\hat{j}$, $\hat{k}$.

c) What is the net electric force acting on $Q_1$? Give both the magnitude and direction.

\[
\left( k = \frac{1}{4\pi\varepsilon_0} \right)
\]
2-(25 Points) A conducting spherical shell that has inner radius $a$ and outer radius $b$ contains a total charge $2Q$. A positive point charge $Q$ is located at the center of the spherical shell.

a) Derive the expression for the electric field magnitude as a function of the distance $r$ from the center for the regions $r < a$, $a < r < b$, and $r > b$.
b) Graph the electric field magnitude as a function of $r$.
c) Find the surface charge density at the inner surface of the conducting shell (at $r = a$).
d) Find the surface charge density at the outer surface of the conducting shell (at $r = b$).
3-(25 Points) Electric charges $+Q_1 > 0$ and $-Q_2 < 0$ are uniformly distributed along line charges of lengths $2L_1$ and $2L_2$ as shown in the figure. The line charges are separated by a distance $d$.

a) Find the electric potential and electric field due to a single line charge at point $P$ (along the perpendicular bisector of the rod) as shown in the figure. (Hint: You may find it easy to use the gradient definition of the electric field in terms of the electric potential).

b) Using the superposition principle find the electric potential due to both line charges at point $P$ as shown in the figure.
4-(25 Points) The figure shows two capacitors. The capacitors are identical except that the left capacitor has a metal slab having thickness $d/2$ (with the same shape and size as the plates) inserted at a distance $x$ from the top plate. The capacitance of the right capacitor is $C_0$. Initially, the switches are open, the voltage across the left capacitor is $V_0$, and the right capacitor is uncharged. Answer the following:

a) Calculate the capacitance of the left capacitor in terms of $C_0$.

b) Suppose that first the switches are closed, and then the metal slab on the left capacitor is pulled out. Calculate the final charge of the left capacitor in terms of $C_0$ and $V_0$.

[Useful formula: $C = \frac{Q}{V}$, $C = \varepsilon_0 \frac{A}{d}$ (capacitance of a parallel plate capacitor)]