Phys 222 Fundamental Physics II-S Test #1

Your name:

Time allowed: 75 minutes

Please answer ALL questions

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This is a closed-book, closed-note, and closed-neighbor exam. You are allowed to have a 3"x5" card with information, a calculator (not a computer), and your writing instruments.
2. Please make sure that all cell phones are set to not disturb others during the exam.
3. There are twelve multiple choice questions and two work out problems.
4. Each multiple choice question has only one correct choice. Please circle the correct answer on the test sheets.
5. Each multiple choice question is worth 5 points. Each work out problem is worth 20 points. The total points are 100 points.
6. You need to write down all the steps in solving the problem .You will NOT receive any credit for correct numerical solutions that are unsupported by adequate work (i.e., you need to write down all the steps in solving the problem).
7. When you are finished you can turn your exam in and leave. Please be respectful of other students who may still be working and be as quite as possible during your egress

Good luck!

MULTIPLE CHOICE QUESTONS

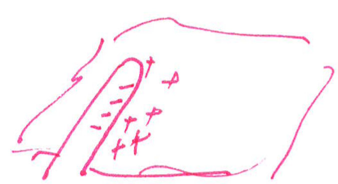
1. Doug rubs a piece of fur on a hard rubber rod, giving the rod a negative charge. What happens?

   a. Protons are removed from the rod.

   b. Electrons are transferred from the fur to the rod.

   c. The fur is also charged negatively.

   d. The fur is left neutral.



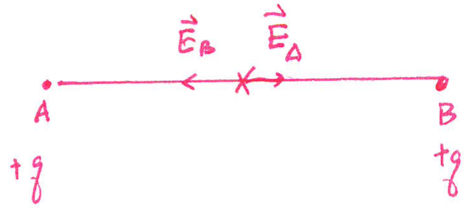
2. Two point charges each have a value of +30.0 mC and are separated by a distance of 4.00 cm. What is the electric field midway between the two charges? ($k_e = 8.99 \times 10^9$ N·m^2/C^2; 1 mC=10^{-3}C)

   a. 40.5×10^7 N/C

   b. 20.3×10^7 N/C

c. 10.1×10^7 N/C

d. zero



$\because |\vec{E}_A| = |\vec{E}_B|$
but opposite directions
$\therefore \vec{E} = \vec{E}_A + \vec{E}_B = 0$

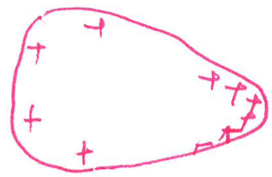
3. Relative distribution of charge density on the surface of a conducting solid depends on:

   a. the shape of the conductor.

   b. mass density of the conductor.

   c. type of metal of which the conductor is made.

   d. strength of the earth's gravitational field.



4. A charge, $+Q$, is placed inside a balloon and the balloon is inflated. As the radius of the balloon r increases the total number of field lines (i.e., the net electric flux) going through the surface of the balloon:

   a. increases proportional to r^2.

   b. increases proportional to r.

   c. stays the same.

   d. decreases as $1/r$.

$\Phi_{net} = \dfrac{Q_{inside}}{\varepsilon_0}$ (Gauss' law)

$\because$ Q_{inside} does not change

$\therefore$ Φ_{net} is unchanged

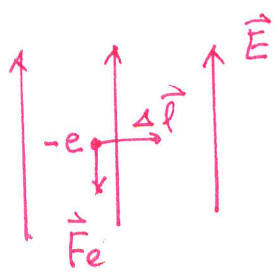
5. An electron (charge -1.6×10^{-19} C) moves on a path perpendicular to the direction of a uniform electric field of strength 3.0 N/C. How much work is done on the electron as it moves 15 cm?

   a. 4.8×10^{-20} J

   b. -4.8×10^{-20} J

   c. 1.6×10^{-20} J

   d. Zero

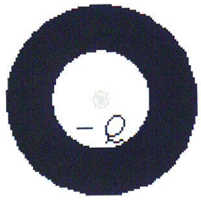


$\because W_{AB} = \vec{F}_e \cdot \Delta\vec{\ell} = |\vec{F}_e||\Delta\ell| \cos 90^\circ = 0$

i.e. $\vec{F}_e \perp \Delta\vec{\ell}$

$\therefore W_{AB} = 0$

6. There is a hollow, conducting, uncharged sphere with a negative charge at the center of the hollow. Consider the electrical potential at the inner and outer surfaces of the sphere. Which of the following is true? (Hint: use the properties of the conducting hollow sphere at its electrostatic equilibrium.)



∵ for conductor at equilibrium

$V_{inside} = V_{surface} = const.$

also $V_\infty = 0$

∴ $V_{inner\ surface} = V_{outer\ surface} = const. \neq 0$

a. The potential on the inner surface is greater.

b. The potential on the outer surface is greater.

c. The potentials on both surfaces are zero.

d. The potentials on both surfaces are equal but not zero.

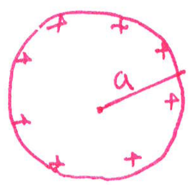
7. A solid conducting sphere of 10 cm radius has a net charge of 20 nC (1 nC=10^{-9} C). If the potential at infinity is taken as zero, what is the potential at the center of the sphere (1 μV=10^{-6} V)?

a. 36 μV

b. 360 μV

c. 1.8×10^3 V

d. $>1.8 \times 10^4$ V



∵ ① $V = k_e \frac{q}{r}$ $\quad r \geq a$

② for a conductor. $V_{inside} = V_{surface}$

and $V_\infty = 0$

∴ $V_{center} = V_{surface} = k_e \frac{q}{a}$ $\quad (r \geq a)$

8. A 20-μF (1μF=10^{-6}F) capacitor is attached across a 1000-V power supply. What is the charge on the capacitor (1 mC=10^{-3}C)?

a. 10 mC

b. 20 mC

c. 40 mC

d. none of the above

∵ $C = \frac{Q}{\Delta V}$ $\quad$ ∴ $Q = C\Delta V$

9. Increasing the separation of the two charged parallel plates of a capacitor, which are disconnected from a battery, will produce what effect on the capacitor?

a. increase charge

b. decrease charge

c. increase capacitance

d. decrease capacitance

∵ $C = \varepsilon_0 \frac{A}{d} \propto \frac{1}{d}$

∴ when d increases, C decrease.

10. If three 4.0-μF capacitors are connected in parallel, what is the combined capacitance?

a. 12 μF

b. 0.75 μF

c. 8.0 μF

d. 0.46 μF

for the capacitors combined in parallel,

$$C_{eq} = C_1 + C_2 + C_3$$

11. A 10.0-μF capacitor is attached to a 20-V power supply. How much energy is stored in the capacitor? (1μF=10^{-6}F)

a. 2.0×10^{-3} J

b. 1.2×10^{-3} J

c. 2.0×10^{-4} J

d. 5.2×10^{-4} J

$$E = \frac{1}{2} C(\Delta V)^2$$

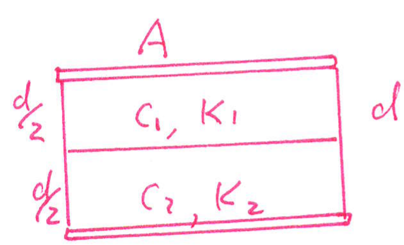
12. A parallel-plate capacitor with plate area *A* and plate separation *d* has a capacitance of 3.0 with the gap between the plates unfilled. The gap is then filled with two dielectric materials, one with dielectric constant 2.0 and the other one with dielectric constant 4.0. Each slab of dielectric has area *A* and thickness *d*/2, the layering of the dielectrics resulting in the gap being completely filled. Which of the following combinations of capacitors will have the same capacitance as the newly filled parallel-plate one?

a. a 6.0- capacitor and a 12- capacitor in parallel

b. a 6.0- capacitor and a 12- capacitor in series

c. a 24- capacitor and a 12- capacitor in parallel

d. a 24- capacitor and a 12- capacitor in series



they are in series

$$C_1 = K_1 C_0' = K_1 \varepsilon_0 \frac{A}{d/2} = 2K_1 C_0$$

$$C_2 = K_2 C_0^2 = K_2 \varepsilon_0 \frac{A}{d/2} = 2K_2 C_0$$

Problem 1

An electric field of intensity 3.50 kN/C (1kN=10^3 N) is applied along the x-axis. Calculate the electric flux through a rectangular plane 0.350 m wide and 0.700 m long if (a) the plane is parallel to the yz-plane, (b) the plane is parallel to the xy-plane, and (c) the plane contains the y-axis and its normal makes an angle of 40.0° with the x-axis.

Solution: The area of the rectangular plane is $A = (0.350 \text{ m})(0.700 \text{ m}) = 0.245 \text{ m}^2$.

(a) When the plane is parallel to the *yz*-plane, its normal line is parallel to the x-axis and makes an angle $\theta = 0°$ with the direction of the field. The flux is then

$$\Phi_E = EA\cos\theta = \left(3.50\times10^3 \text{ N/C}\right)\left(0.245 \text{ m}^2\right)\cos 0° = \boxed{858 \text{ N}\cdot\text{m}^2/\text{C}}$$

(b) When the plane is parallel to the *x*-axis, $\theta = 90°$ and $\Phi_E = \boxed{0}$.

(c) $\Phi_E = EA\cos\theta = \left(3.50\times10^3 \text{ N/C}\right)\left(0.245 \text{ m}^2\right)\cos 40.0° = \boxed{657 \text{ N}\cdot\text{m}^2/\text{C}}$

Problem 2

A parallel-plate capacitor has capacitance 3.00 μF (1 μF=10^{-6} F). (a) How much energy is stored in the capacitor if it is connected to a 6.00-V battery? (b) If the battery is disconnected and the distance between the charged plates doubled, what is the energy stored? (c) The battery is subsequently reattached to the capacitor, but the plate separation remains as in part (b). How much energy is stored?

Solution: (a) The energy initially stored in the capacitor is

$$(\text{Energy stored})_1 = \frac{Q_i^2}{2C_i} = \frac{1}{2}C_i(\Delta V)_i^2 = \frac{1}{2}(3.00\ \mu\text{F})(6.00\ \text{V})^2 = \boxed{54.0\ \mu\text{J}}$$

(b) When the capacitor is disconnected from the battery, the stored charge becomes isolated with no way off the plates. Thus, the charge remains constant at the value Q_i as long as the capacitor remains disconnected. Since the capacitance of a parallel-plate capacitor is $C = \kappa \in_0 A/d$, when the distance d separating the plates is doubled, the capacitance is decreased by a factor of 2 $\left(C_f = C_i/2 = 1.50\ \mu\text{F}\right)$. The stored energy (with Q unchanged) becomes

$$(\text{Energy stored})_2 = \frac{Q_i^2}{2C_f} = \frac{Q_i^2}{2(C_i/2)} = 2\left(\frac{Q_i^2}{2C_i}\right) = 2(\text{Energy stored})_1 = \boxed{108\ \mu\text{J}}$$

(c) When the capacitor is reconnected to the battery, the potential difference between the plates is re-established at the original value of $\Delta V = (\Delta V)_i = 6.00\ \text{V}$, while the capacitance remains at $C_f = C_i/2 = 1.50\ \mu\text{F}$. The energy stored under these conditions is

$$(\text{Energy stored})_3 = \frac{1}{2}C_f(\Delta V)_i^2 = \frac{1}{2}(1.50\ \mu\text{F})(6.00\ \text{V})^2 = \boxed{27.0\ \mu\text{J}}$$