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University of California, Berkeley

Mid-term Examination 2 Physics 7B, Section 3

6:00 pm - 8:00 pm, November 4, 2008

Name:____

SID No:_______________________________________

Discussion Section:____________________________

Name of TA:__________________________________

Problem 1	
Problem 2	
Problem 3	
Problem 4	
Problem 5	
Problem 6	

Score:____

Answer all six problems. Write clearly and explain your work. Partial credit will be given for incomplete solutions provided your logic is reasonable and clear. Cross out any parts that you don't want to be graded. Enclose your answers with boxes. **Express all numerical answers in SI units**. Answers with no explanation or disconnected comments will not be credited. If you obtain an answer that is questionable, explain why you think it is wrong.

Constants and Conversion factors
Some useful equations

Avogadro number, N_A	6.022×10^{23}
Permittivity of vacuum, ϵ_0	8.85×10^{-12} F·m^{-1}
Permeability of vacuum, μ_0	$4\pi \times 10^{-7}$ T·m·A^{-1}
Charge of electron, $q_e = -e$	-1.602×10^{-19} C
Mass of electron, m_e	9.11×10^{-31} kg
Universal gas constant, R	8.315 J·mol^{-1}·K^{-1} = 1.99 cal·mol^{-1}·K^{-1}
Boltzmann constant, k	1.381×10^{-23} J·K^{-1}
Stefan-Boltzmann constant, σ	5.67×10^{-8} W·m^{-2}·K^{-4}
Acceleration due to gravity, g	9.8 m·s^{-2}
Specific heat of water	1 kcal·kg^{-1}·°C^{-1}
Heat of fusion of water	80 kcal·kg^{-1}
1 atm	1.013×10^5 N·m^{-2}
1 kcal	4.18×10^3 J
1 hp	746 W

$$\begin{aligned}
\textit{Coulomb's law}: \ \mathbf{F} &= \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}\hat{\mathbf{r}} \\
\textit{Electric field}: \ d\mathbf{E} &= \frac{1}{4\pi\epsilon_0}\frac{dq}{r^2}\hat{\mathbf{r}} \\
\textit{Electric dipole}: \ \mathbf{p} &= q\mathbf{d} \\
\textit{Torque on a dipole}: \ \vec{\tau} &= \mathbf{p} \times \mathbf{E} \\
\textit{Potential energy of a dipole}: \ U &= -\mathbf{p} \cdot \mathbf{E} \\
\textit{Gauss's law}: \ \oint \mathbf{E} \cdot d\mathbf{A} &= \frac{q_{encl}}{\epsilon_0} \\
\textit{Potential difference}: \ V_{ab} &= -\int_a^b \mathbf{E} \cdot d\mathbf{l} \\
\textit{Potential}: \ dV &= \frac{1}{4\pi\epsilon_0}\frac{dq}{r} \\
\textit{Potential energy}: \ U_{ab} &= qV_{ab} \\
\textit{Electric field and potential}: \ \mathbf{E} &= -\nabla V \\
\textit{Capacitance}: \ C &= \frac{q}{V_{ab}}
\end{aligned}$$

$$\begin{aligned}
Capacitors\ in\ series:\ \frac{1}{C_{eq}} &= \sum \frac{1}{C_i} \\
Capacitors\ in\ parallel;\ C_{eq} &= \sum C_i \\
Energy\ stored\ in\ a\ capacitor:\ U &= \frac{1}{2}CV^2 \\
Energy\ density:\ u &= \frac{1}{2}\epsilon_0 E^2 \\
Current:\ I &= \frac{dq}{dt} \\
Current\ and\ current\ density:\ dI &= \mathbf{j}\cdot d\mathbf{A} \\
Ohm's\ law:\ V &= IR \\
Ohm's\ law:\ \mathbf{j} &= \sigma\mathbf{E}; \quad \mathbf{E} = \rho\mathbf{j} \\
Resistivity\ and\ resistance:\ R &= \rho\frac{l}{A} \\
Electric\ power\ (dc)\ delivered:\ P &= VI \\
Electric\ power\ (dc)\ dissipated:\ P &= V^2/R = I^2R \\
Average\ electric\ power\ (ac)\ delivered:\ \overline{P} &= I_{rms}V_{rms} = I_0V_0/2 \\
Average\ electric\ power\ (ac)\ dissipated:\ \overline{P} &= I_{rms}^2R = I_0^2R/2 \\
rms\ current:\ I_{rms} &= I_0/\sqrt{2} \\
rms\ voltage\ V_{rms} &= V_0/\sqrt{2} \\
Resistors\ in\ series:\ R_{eq} &= \sum R_i \\
Resistors\ in\ parallel:\ \frac{1}{R_{eq}} &= \sum \frac{1}{R_i} \\
Kirchhoff\ current\ rule:\ \sum I &= 0\ \ at\ a\ node \\
Kirchhoff\ potential\ rule:\ \sum \Delta V &= \sum IR\ \ around\ a\ loop \\
\nabla V &= \frac{\partial V}{\partial x}\hat{\mathbf{x}} + \frac{\partial V}{\partial y}\hat{\mathbf{y}} + \frac{\partial V}{\partial z}\hat{\mathbf{z}} \\
\nabla V &= \frac{\partial V}{\partial r}\hat{\mathbf{r}} + \frac{1}{r}\frac{\partial V}{\partial \phi}\hat{\phi} + \frac{\partial V}{\partial z}\hat{\mathbf{z}} \\
\nabla V &= \frac{\partial V}{\partial r}\hat{\mathbf{r}} + \frac{1}{r}\frac{\partial V}{\partial \theta}\hat{\theta} + \frac{1}{rsin\theta}\frac{\partial V}{\partial \phi}\hat{\phi}
\end{aligned}$$

Some useful Integrals:

$$\int \frac{dx}{\sqrt{x^2+a^2}} = log\left(x + \sqrt{x^2+a^2}\right) \quad \text{or} \quad sinh^{-1}\frac{x}{a}$$

$$\int \frac{dx}{x^2+a^2} = \frac{1}{a}arctan(\frac{x}{a}) \qquad \int \frac{dx}{(x^2+a^2)^{3/2}} = \frac{x}{a^2\sqrt{x^2+a^2}}$$

Table 1: Dielectric Constants for Some Materials

Material	Dielectric Constant K	Dielectric Break Down (V/m)
Vacuum	1.0000	$> 10^{15}$
Air	1.0006	3×10^6
Teflon	2.1	60×10^6
Paraffin	2.2	10×10^6
Polystyrene	2.6	24×10^6
Vinyl (plastic)	2 - 4	50×10^6
Paper	3.7	15×10^6
Quartz	4.3	8×10^6
Oil	4	12×10^6
Glass Pyrex	5	14×10^6
Porcelain	6 - 8	5×10^6
Mica	7	150×10^6
Silicon Dioxide	3.9	$5 - 15 \times 10^6$
Silicon	11.68	$- \times 10^6$
Water (liquid)	80	—
Strontium titanate	300	8×10^6

Table 2: Resistivity for Some Materials

Material	Resistivity ρ ($\Omega \cdot m$)	Temperature Coefficient $\alpha(°C)^{-1}$ at 20°C
Conductors		
Copper	1.59×10^{-8}	0.0061
Silver	1.68×10^{-8}	0.0068
Gold	2.44×10^{-8}	0.0034
Aluminum	2.65×10^{-8}	0.00429
Tungsten	5.6×10^{-8}	0.0045
Iron	9.71×10^{-8}	0.00651
Platinum	10.6×10^{-8}	0.003927
Mercury	98×10^{-8}	0.0009
Nichrome	100×10^{-8}	0.0004
Semiconductors		
Carbon (graphite)	$(3 - 60) \times 10^{-5}$	-0.0005
Germanium	$(1 - 500) \times 10^{-3}$	-0.05
Silicon	0.1- 60	-0.07
Insulators		
Glass	$10^9 - 10^{12}$	
Hard Rubber	$10^{13} - 10^{15}$	
Silicon Dioxide	$10^{14} - 10^{16}$	

1. [40 points] **Short Questions**

(a) [10 points] Circle T or F for True or False

T F (i) The total electric charge of an isolated system remains constant regardless of changes within the system itself.

T F (ii) A plasma is a poor conductor.

T F (iii) Any two opposite charges make a dipole.

T F (iv) The superposition principle for electric fields is well confirmed by experiment.

T F (v) A insulator's electrons are not free to move under electrical force.

T F (vi) Gauss's law is always valid.

T F (vii) The inverse of resistance and resistivity is conductance and conductivity.

T F (viii) The electric field is a vector field with SI units of Newtons per Coulomb (N/C) or, equivalently, volts per meter (V/m). The strength of the field at a given point is defined as the force that would be exerted on a positive test charge of +1 Coulomb placed at that point; the direction of the field is given by the direction of that force.

T F (ix) The capacitance of a collection of charges is determined solely by the geometry of the charge distribution.

T F (x) Electric charge is a characteristic of subatomic particles, and is quantized when expressed as a multiple of the so-called elementary charge $e = 1.6 \times 10^{-19}$ C.

T F (xi) An electric battery is composed of two dissimilar metals (or appropriate material such as carbon) and a solution called an electrolyte.

T F (xii) In order to have a steady-state electric current one needs a complete circuit.

T F (xiii) Conductivity plus Resistivity of a material is equal to one.

T F (xiv) In the microscopic model of electric current the validity of Ohm's law requires the electrons moving with a high velocity and drifting with a much lower one.

T F (xv) The lethal electric shock is around 0.1 Amperes (100 mA) for a period of a second or more.

T F (xvi) The electric flux is how much electric field passes through a surface per unit time.

T F (xvii) The electric potential is equal to the electric potential energy.

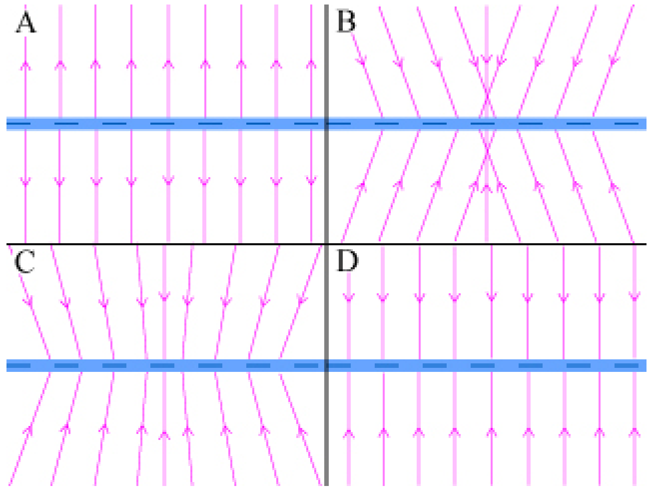
T F (xviii) A capacitor can store electric charge.

T F (xix) Electrical Resistivity depends upon Temperature .

T F (xx) Kirchhoff's Rules are really only conservation of charge and energy.

(b) [10 points] Circle correct answer Electrostatics

(i) Which of the following figures correctly depicts the field lines from an infinite uniformly negatively charged sheet? Note that the sheet is being viewed edge-on in all pictures.



(ii) In the diagram from part (i), what is wrong with figure B? (Pick only those statements that apply to figure B.) Circle all that apply.

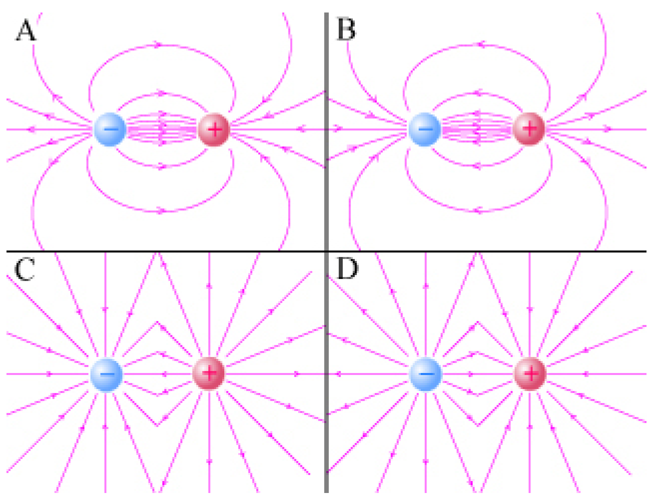
(A) Field lines cannot cross each other.

(B) The field lines should be parallel because of the sheet's symmetry.

(C) The field lines should spread apart as they leave the sheet to indicate the weakening of the field with distance.

(D) The field lines should always end on negative charges or at infinity.

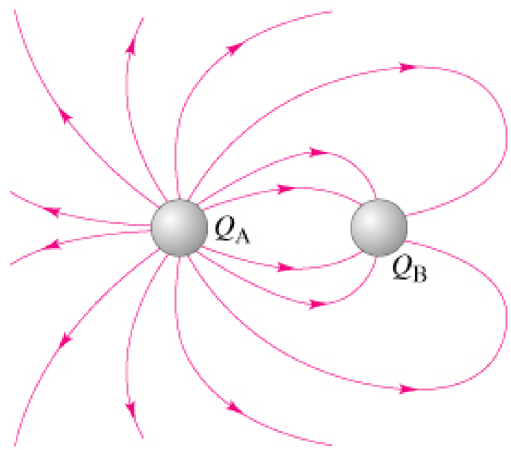
(iii) Which of the following figures shows the correct electric field lines for an electric dipole?



(iv) In the diagram from (iii) (Part D of figure), what is wrong with figure D? (Pick only those statements that apply to figure D.) Circle all that apply.

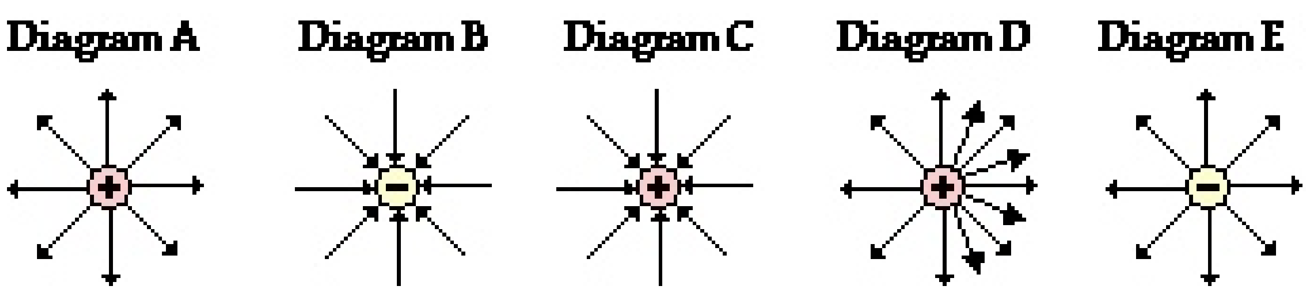
(A) Field lines cannot cross each other.
(B) The field lines should turn sharply as you move from one charge to the other.
(C) The field lines should be smooth curves in vacuum.
(D) The field lines should always end on negative charges or at infinity

(v) In the figure below, the electric field lines are shown for a system of two point charges, Q_A and Q_B. Which of the following could represent the magnitudes and signs of Q_A and Q_B? In the following, take q to be a positive quantity.



(A) $Q_A = \ +q$ and $Q_B = -q$.
(B) $Q_A = +7q$ and $Q_B = -3q$.
(C) $Q_A = +3q$ and $Q_B = -7q$.
(D) $Q_A = -3q$ and $Q_B = +7q$.
(E) $Q_A = -7q$ and $Q_B = +3q$.
(F) All are correct.

(vi) Several electric field line patterns are shown in the diagrams below. Which of these patterns are incorrect? Circle the letter of the incorrect patterns and explain what is wrong with all incorrect diagrams.



(vii) There are several ways to produce electrostatic charging. Which is **not** one?

(A) Rubbing two dissimilar materials together.
(B) Induction.
(C) Contact.
(D) Radio broadcast.
(E) Electric Sparking.
(F) None cause electrostatic charging.

(viii) A neutral conducting sphere of radius r is located a distance d from a dust particle of charge q. The conducting sphere exerts a force on the charged particle which is

(A) zero. (no net force)
(B) repulsive.
(C) attractive.
(D) not enough information to determine.

(ix) A fixed potential difference V exists between a pair of close parallel plates carrying opposite charges +Q and -Q. Which of the following would **not** increase the magnitude of charge that you could put on the plates?

(A) Increase the size of the plates.
(B) Move the plates farther apart.
(C) Fill the space between the plates with paper.
(D) Increased the fixed potential difference V.
(E) None of the above.

(x) Sharper Image and other producers makes substantial profit from selling ion generators (electrode creates negative ions in the air) as air cleaner and antibacterial agent. How does generating negative ions clear the air of dust and bacteria?

(A) The ions are attracted to the dust and bacteria by polarizing them and make them charged. The dust is then attracted to any polarizable surface and sticks.

(B) The ions are attracted to the dust and bacteria and chemically react to disassemble them.

(C) The ions are attracted to the dust and bacteria and make them effectively charged. Since the Earth is positively charged by the large thunderstorms in the Amazon, the dust and bacteria are attracted to the floor.

(D) The coronel discharge that makes the negative ions is like a spark and actually burns up the dust and bacteria.

(E) It does not really work but the negative ions smell like fresh bleach so that people think the air is cleaner.

(c) [10 points] Concentric Cylinders

(c.1) [2 points] Without doing any calculation, draw eight electric field lines (solid) and four equipotential contours (dotted) in the electrical system shown in Figure 1 consisting of two concentric cylinders with charge $+q$ per unit length on the inner cylinder and q per unit length on the outer cylinder. Label the potential contours so that $V_1 > V_2 > V_3 > V_4$. Explicitly label any regions where the electric field is zero.

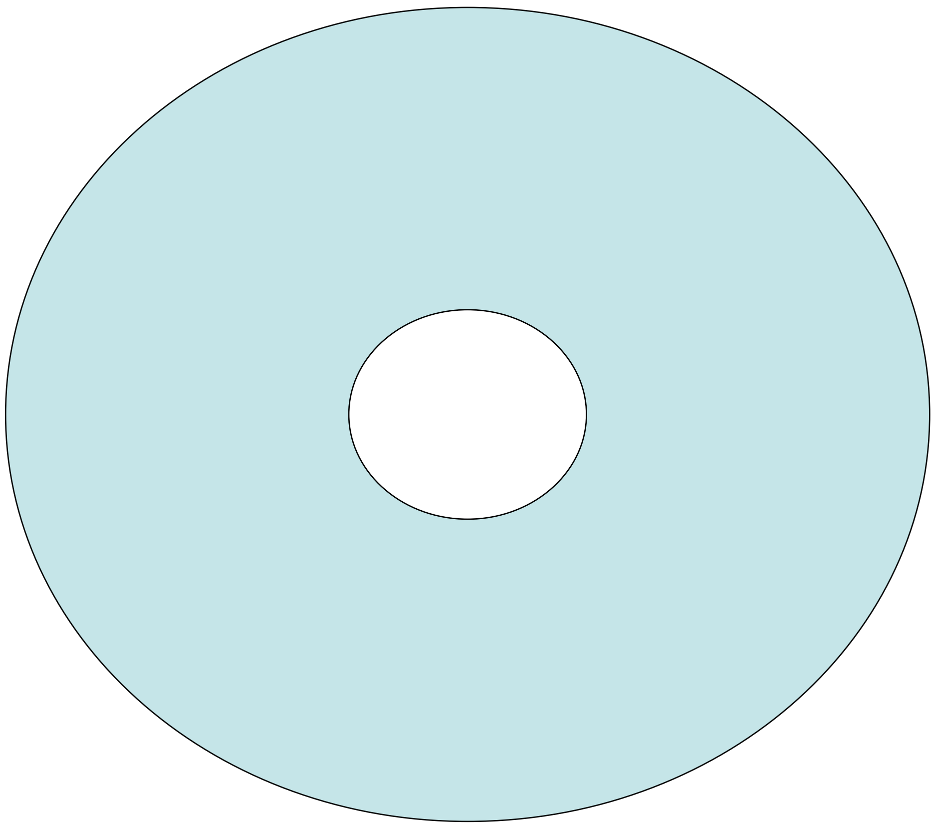


Figure 1: Figure for problem 1(c) showing two concentric cylinders with charge $+q$ per unit length on the inner cylinder and q per unit length on the outer cylinder.

(c.2) [2 points] What is an expression for the electric field in terms of the charge q and the radius given r_1 and r_2 are the inner and outer radii?

(c.3) [2 points] What is an expression for the potential V as a function of radius r? Set $V(r = 0) = 0$.

(c.4) [2 points] What is the stored energy per unit length in the system at voltage V?

(c.5) [2 points] If the shaded region in between the cylinders is filled with a dielectric material with constant K while keeping the charge per unit length fixed, how do the quantities calculated in parts c.2, c.3, and c.4 change? Briefly describe your reasoning.

(d) [10 points] Two spheres placed far apart are positively charged to the same potential (as they are connected by a thin conducting wire) as seen in Figure 2. The radius r_s of the smaller spherical end is about half of the radius r_l of the larger end.

(d.1) [4 points] Sketch in the figure the distribution of the positive charges and the electric field lines. (See question sections below first.)

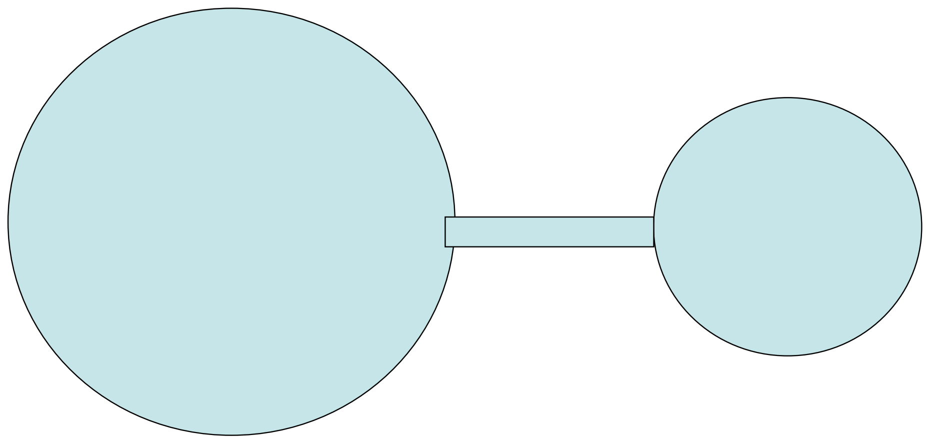


Figure 2: Figure for problem 1(d) Two conducting spheres one with twice the diameter as the other and the two are connected by a conductor.

Explain your reasoning:

(d.2) [2 points] Give an expression for the charge q_i on each sphere for potential V.

(d.3) [2 points] Give an expression for the electric field magnitude at the surface of each sphere for potential V.

(d.4) [2 points] Give an expression for the electric field magnitude at the surface of any convex conductor (radius of curvature r) at potential V. Explain why forks are more dangerous in microwave ovens than spoons.

2. [25 points] Electrical Effects

(a) [7 points] Circle correct answer Electrostatics

(i) What is the instaneous force exerted on the electron in a hydrogen atom by its proton when their mean separation is 0.53×10^{-10} m.
(A) $4.4 \times 10^{-18}\hat{r}$ N (B) $5 \times 10^{-8}\hat{r}$ N (C) $8 \times 10^{-8}\hat{r}$ N (D) $8 \times 10^{-7}\hat{r}$ N (E) $156\hat{r}$ N
(F) $-4.4 \times 10^{-18}\hat{r}$ N (G) $-5 \times 10^{-8}\hat{r}$ N (H) $-8 \times 10^{-8}\hat{r}$ N (I) $-8 \times 10^{-7}\hat{r}$ N (J) $-156\hat{r}$ N
(K) 0 N since the electron is all around the proton in all directions equally

(ii) What is the electric field at the radius, $r = 0.53 \times 10^{-10}$ m, from the center of a proton?
(A) $5 \times 10^{6}\hat{r}$ N/C (B) $5 \times 10^{7}\hat{r}$ N/C (C) $5 \times 10^{8}\hat{r}$ N/C (D) $5 \times 10^{9}\hat{r}$ N/C (E) $5 \times 10^{10}\hat{r}$ N/C (F) $5 \times 10^{11}\hat{r}$ N/C
(G) $-5 \times 10^{6}\hat{r}$ N/C (H) $-5 \times 10^{7}\hat{r}$ N/C (J) $-5 \times 10^{8}\hat{r}$ N/C (K) $-5 \times 10^{9}\hat{r}$ N/C (L) $-5 \times 10^{10}\hat{r}$ N/C (M) $-5 \times 10^{11}\hat{r}$ N/C

(iii) What is the electric potential at the radius, $r = 0.53 \times 10^{-10}$ m, from the center of a proton, if $V(\infty) = 0$?
(A) 6.8 V (B) 13.6 V (C) 27.2 V (D) 54.4 V
(E) -6.8 V (F) -13.6 V (G) -27.2 V (H) -54.4 V

(iv) What is the electric field strength near a large flat insulating disk with surface charge density $\sigma = 10^{-4} C/m^2$?
(A) 5.6×10^{6} N/C (B) 5.6×10^{7} N/C (C) 5.6×10^{8} N/C
(D) 5.6×10^{9} N/C (E) 5.6×10^{10} N/C (F) 5.6×10^{11} N/C

(iv) The dipole moment of a water molecule is $6.1 \times 10^{-30} C \cdot m$. If the distance between the two hydrogen atoms and the oxygen atom is 10^{-10}m in the direction of the resultant dipole, what is the net positive charge on each hydrogen atom?
(A) $1e = 1.6 \times 10^{-19} C$ (B) 0.8 e (C) 0.6 e (D) 0.4 e (E) 0.2 e

(v) The dipole moment of a water molecule is $6.1 \times 10^{-30} C \cdot m$. What is the torque on a water molecule molecule if its dipole vector is at right angles to an electric field of $E = 5 \times 10^{4} N/C$
(A) $3 \times 10^{-30} N \cdot m$ (B) $3 \times 10^{-25} N \cdot m$ (C) $3 \times 10^{-20} N \cdot m$
(D) 0 (E) $1.2 \times 10^{-36} N \cdot m$

(vi) What is the electric flux through a sphere encircling a free electron?
(A) $1.81 \times 10^{-10} Nm^2/C$ (B) $1.81 \times 10^{-9} Nm^2/C$ (C) $1.81 \times 10^{-8} Nm^2/C$ (D) $1.81 \times 10^{-7} Nm^2/C$ (E) $1.81 \times 10^{-6} Nm^2/C$
(F) $-1.81 \times 10^{-10} Nm^2/C$ (G) $-1.81 \times 10^{-9} Nm^2/C$ (H) $-1.81 \times 10^{-8} Nm^2/C$ (I) $-1.81 \times 10^{-7} Nm^2/C$ (J) $-1.81 \times 10^{-6} Nm^2/C$

(vii) A Gaussian surface with one portion inside of a conductor encloses a flux of $2 \times 10^{5} Nm^2/C$. How much surface charge on the conductor is enclosed by the Gaussian surface?
(A) $1.77 \times 10^{-6} C$ (B) $1.77 \times 10^{-5} C$ (C) $1.77 \times 10^{-4} C$ (D) $1.77 \times 10^{-3} C$
(E) $1.77 \times 10^{-2} C$ (F) $1.77 \times 10^{-1} C$ (G) $1.77 C$ (H) $17.7 C$

(b) [3 points] Circle correct answer **The Earth's Field**

(i) The Earth has an electric field which has an average magnitude of 150 N/C near its surface. The field points radially inward. The radius of the Earth is 6371 km. What is the net charge of the Earth?

(A) $7C$ (B) $68C$ (C) $677C$ (D) $6771C$ (E) $6.8 \times 10^4 C$ (F) $6.8 \times 10^5 C$ (G) $6.8 \times 10^6 C$

(A) -$7C$ (B) $-68C$ (C) $-677C$ (D) $-6771C$ (E) $-6.8 \times 10^4 C$ (F) $-6.8 \times 10^5 C$ (G) $-6.8 \times 10^6 C$

(ii) The Earth has an electric field which has an average magnitude of 150 N/C near its surface. The field points radially inward. The radius of the Earth is 6371 km. What is the voltage of the Earth? (Assume zero potential at infinity.)

(A) $10^9 V$ (B) $10^6 V$ (C) $10^3 V$ (D) $0V$ (E) $-10^3 V$ (F) $-10^6 V$ (G) $-10^9 V$

(iii) A human standing on the surface of the Earth is at the same potential as the surface of the Earth. According to the figure, what is the best description of the effective electrical behaviour of a human?

(A) an insulator
(B) a good conductor
(C) a poor conductor
(D) a semiconductor
(E) a superconductor
(F) a lightening rod

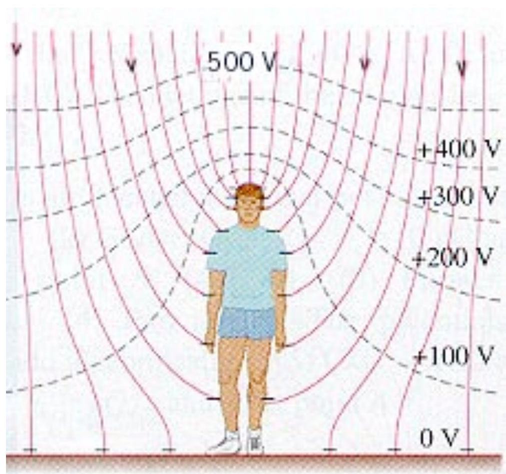


Figure 3: Figure for problem 2(b)(iii) showing human standing on the Earth.

(c) [5 points] Circle correct answer

(i) How many electrons pass a point in a circuit per second when there is a current of 1 A?

(A) 6×10^{15}
(B) 6×10^{16}
(C) 6×10^{17}
(D) 6×10^{18}
(E) 6×10^{19}

(ii) My large flash light uses four 1.5 V D-cell batteries in series and draws 0.3 Amps. What is the resistance of the shining bulb?

(A) 1.5 Ohms
(B) 4.5 Ohms
(C) 15 Ohms
(D) 20 Ohms
(E) 45 Ohms
(F) 450 Ohms

(iii) An electric heater operates at 1100 Watts from the 120 VAC wall outlet. What rms current does it draw?

(A) 7 A
(B) 8 A
(C) 9 A
(D) 10 A
(E) 11 A
(F) 12 A

(iv) Heavy duty household 10-gauge copper electric wire has a diameter of 2.58826 mm. The electrical resistivity of copper is $\rho = 1.68 \times 10^{-8}\Omega \cdot m$. What is the resistance of 1000 ft (305 m)?

(A) 0.1Ω
(B) 1Ω
(C) 10Ω
(D) 100Ω
(E) 1000Ω

(v) The resistance of household wire to a hair dryer is 0.3 Ω before turning on the hair dryer and its temperature rises because of Ohmic heating by 15°C with five minutes use. If the temperature coefficient of resistivity of copper is 0.0068 $^\circ C^{-1}$, what is the resistance of the wire then?

(A) 0.3003Ω
(B) 0.303Ω
(C) 0.33Ω
(D) 0.6Ω
(E) 3.3Ω

(d) [5 points] Circle correct answer

(i) The lowest AC current that can cause ventricular fribillation is?

(A) 1 mA
(B) 10 mA
(C) 100 mA
(D) 1 A
(E) 10 A

(ii) If the internal resistance of a person is 200 Ohms over a distance of 0.2 m and area of 0.1 m by 0.1 m, then what is the resistivity ρ inside a human?

(A) 1 $\Omega \cdot m$
(B) 10 $\Omega \cdot m$
(C) 100 $\Omega \cdot m$
(D) 1000 $\Omega \cdot m$
(E) 4000 $\Omega \cdot m$

(iii) What is the electric field in a medium with resistivity $\rho = 1\ \Omega \cdot m$ carrying a current density of $J = 10A/m^2$?

(A) 0.1 V/m
(B) 1 V/m
(C) 10 V/m
(D) 100 V/m
(E) 1000 V/m
(F) 0.01 V/m

(iv) If the current density is $J = 10A/m^2$ moves at 60° to an area of $A = 0.01m^2$, what is the total current through A?

(A) 1 mA
(B) 5 mA
(C) 10 mA
(D) 50 mA
(E) 100 mA

(v) If the peak of AC current is 15 A, what is the RMS current I_{rms}?

(A) 1 A
(B) 10.6 A
(C) 15 A
(D) 21.2 A
(E) 120 VAC

(e) [5 points] Circle correct answer

(i) A biological battery called an electroplaque produces an EMF of 0.15 V and has an internal resistance of 0.25 Ohms. What net voltage does this electroplaque produce for a 20 mA current?

(A) 0.01 V
(B) 0.05 V
(C) 0.10 V
(D) 0.145 V
(E) 0.2 V

(ii) If four 10-Ohm resistors are put in parallel, what is the equivalent resistance?

(A) 0.25 Ohm
(B) 1 Ohm
(C) 2.5 Ohms
(D) 10 Ohms
(E) 40 Ohms

(iii) If four 10 pF capacitors are put in series, what is the equivalent capacitor?

(A) 2.5 pF
(B) 10 pF
(C) 25 pF
(D) 40 pF
(E) 100 pF
(F) 250 pF

(iv) If four 10 Volt batteries are put in parallel, what is the equivalent battery voltage?

(A) 2.5 V
(B) 4 V
(C) 10 V
(D) 25 V
(E) 40 V

(v) If the charge on a fixed capacitor is doubled, the energy stored in the capacitor

(A) halves.
(B) is unchanged.
(C) doubles.
(D) quadruples.
(E) triples.
(F) is quartered.

3. [20 points] **High Voltage Transmission of Power**

(a) [5 points] **At 300,000 Volts and Still Alive:** A Physics 7B student goes parasailing. By accident the student lands on the lower line of a high voltage transmission line. Electrons flow briefly onto this student's body, lowering her potential to -300,000 volts, the same as the wire's potential. How close could her hand or foot come to the tower (which is grounded, V = 0) without her being electrocuted? Explain your answer.

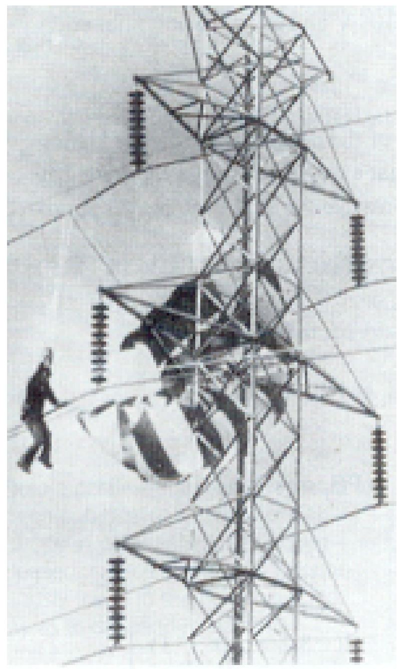


Figure 4: Student on power line.

(b) [7 points] As of 1980, the longest cost-effective distance for electricity transmission was 4,000 miles (7,000 km), although all present transmission lines are considerably shorter. It operated as a +/-300,000 V DC power line. The voltage is boosted to keep it constant. The resistance for the electrical transmission wire is about 0.31 Ohms/km.
(b.1) Find a formula for the power loss P_{loss} as a function of the power transmitted, P the total voltage difference V and the resistance $R = 0.31L$, where L is the distance.

(b.2) If the transmission losses were 20% for this longest distance transmission, what was the delived power?

(b.3) **Highest Voltage Systems** The current highest transmission voltage (DC) is +/-600 kV on HVDC Itaipu (Brazil). China is building a very high voltage power transmission system that will transmit electricity at a DC voltage of +/- 800 kV. At the same time this project will have a power transmission capacity of 5000 MW = 5 Gigawatts, by running 4 wires in parallel for each voltage. The system is scheduled to commence commercial service by mid-2010. In future the electricity generated by several hydro-electric power plants will be transported from Yunnan via 1,400 km to Guangzhou over this long-distance HVDC link.

What is the current and how much power is lost in the transmission? If the cross-sectional area of the wire were halved relative to that of part (b) because copper is so much more expensive now, then what would be the losses?

(c) [8 points] **Superconducting cables** High-temperature superconductors promise to revolutionize power distribution by providing lossless transmission of electrical power. The development of superconductors with transition temperatures higher than the boiling point of liquid nitrogen has made the concept of superconducting power lines commercially feasible, at least for high-load applications. It has been estimated that the waste would be halved using this method, since the necessary refrigeration equipment would consume about half the power saved by the elimination of the majority of resistive losses. Such cables are particularly suited to high load density areas such as the business district of large cities, where purchase of a wayleave for cables would be very costly.

In 2006 Chubu University in Japan performed an experiment with a superconducting cable that could carry a current of 2,200 A and was insulated to withstand 20 KV operating at a temperature in range of 72 K to 80 K.

(c.1) How much power could this superconducting cable carry?

(c.2) What is the power cost of refrigeration per unit length assuming that at 80 K the refrigeration consumed half the power lost in a comparable (0.31 Ohm/km) normal conductor?

(c.3)If the cable can carry 20% more current, when cooled to 40 K, what is the maximum power and the net gain in power transmitted (i.e. account for the extra refrigerator power)? Assume that the heat leak is unchanged going to the lower temperature and the refrigerator efficiency keeps the same ratio to ideal and $T_H = 300\text{K}$.

4. [30 points] A nonconducting sphere has a uniform charge density ρ and an outer radius R_a. It is hollowed out to an inner radius R_b.

(a) [5 points] Apply Gauss's law to determine the electric field $\mathbf{E}(\mathbf{r})$ as a function of r.

(b) [5 points] Starting from the electric field found in part (a), determine the potential $V(r)$ as a function of radius r. Set $V(\infty) = 0$. Plot both the electric field $\mathbf{E}(\mathrm{r})$ and the potential $V(r)$ for the region $0 \leq r \leq 2R_a$.

(c) [6 points] The nonconducting sphere is replaced with two conducting spherical shells with the same two radii R_a and R_b and one is given charge $+q$ and the other $-q$. Calculate the stored energy and capacitance of this charge configuration.

(d) [6 points] A dielectric fluid is then used to fill the space between the conducting spheres. If the dielectric constant of the fluid is κ, find the capacitance of the system after the fluid is in place. What if the fluid only filled the volume out to radius R_c where $R_b < R_c < R_a$?

(e) [6 points] How much work was done to move the fluid in from far away to its final position between the spheres?

(f) [2 points] Now the dielectric is removed and a conducting wire joins the two plates together. A charge +Q is introduced into the region between the spheres. What is the net charge on the facing surfaces of the two spheres? Why?

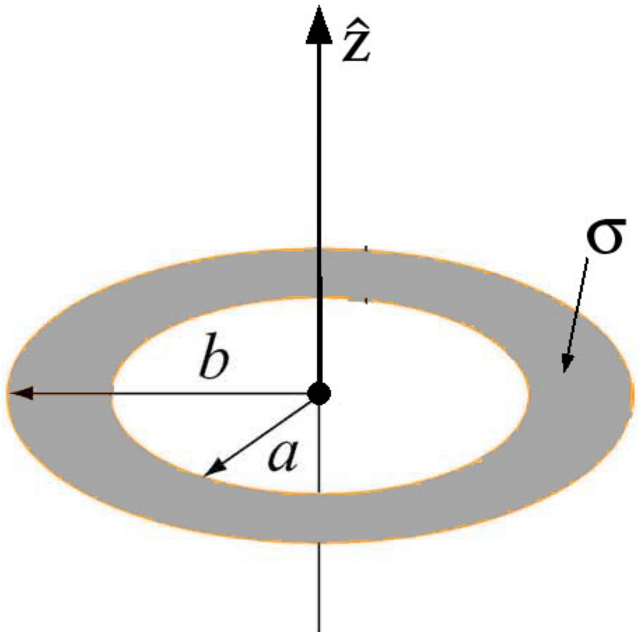


Figure 5: Figure for problem 5

5. [20 points] The flat circular disk ring of charge in Figure 5 has an inner radius of a, an outer radius b and a uniform surface charge density σ from $r = a$ to $r = b$.
(a) [6 points] Find the potential $V(z)$ at a point that is at a vertical distance z from the center of the disk if $V(\infty) = 0$.

(b) [4 points] A charge q with mass m is placed on axis just above the center of the annulus. How fast will it be moving when it is infinitely far away along the axis

(c) [5 points] Determine the associated electric field $\mathbf{E}(\mathbf{z})$ using the relation $\mathbf{E} = -\nabla V$.

(d) [5 points] Determine the associated electric field $\mathbf{E}(\mathbf{z})$ by summing the field for each dq.

6. [30 points] **Complicated Resistor Network**

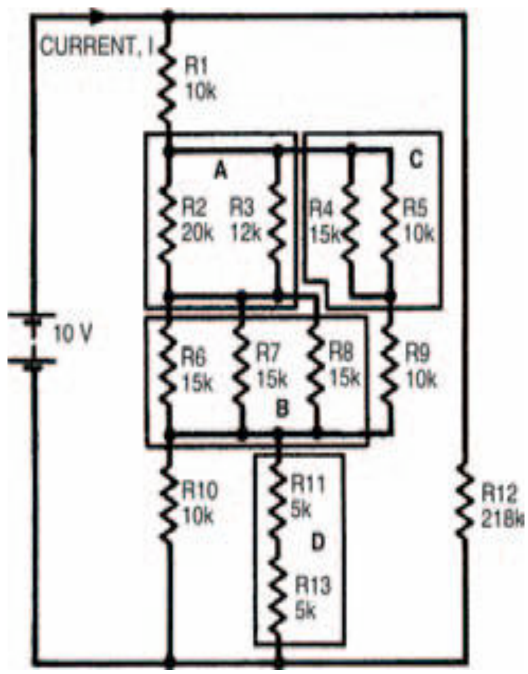


Figure 6: Figure showing complicated resistor network for problem 6

(a) [2 points] What is the current through resistor R12?

(b) [8 points] What are the equivalent resistors R_A, R_B, R_C, and R_D?

(c) [8 points] Draw a new resistor network with the equivalent resistors next to the original. Now chose new boxes and determine the reduced equivalent resistors that shows the most allowed reduction in total number of resistors. Drawing the second reduction equivalent resistor circuit.

(d) [4 points] Now choose new boxes and determine the reduced equivalent resistors that produces the smallest total number of resistors. Draw the equivalent circuit here.

(e) [4 points] Now choose new boxes and determine the reduced equivalent resistors that produces the smallest total number of resistors. Draw the circuit here.

(f) [4 points] Complete the process and find the final equivalent resistance and determine the total current I.

End of Examination