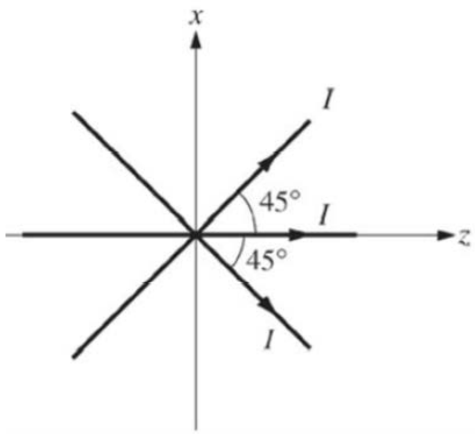
Problem 1:




Three long, straight wires in the $xz$-plane, each carrying current $I$, cross at the origin of coordinates, as shown in the figure above. Let $\hat{\mathbf{x}}$, $\hat{\mathbf{y}}$, and $\hat{\mathbf{z}}$ denote the unit vectors in the $x$-, $y$-, and $z$-directions, respectively. The magnetic field $\mathbf{B}$ as a function of $x$, with $y = 0$ and $z = 0$, is

(A) $\mathbf{B} = \frac{3\mu_0 I}{2\pi x}\hat{\mathbf{x}}$

(B) $\mathbf{B} = \frac{3\mu_0 I}{2\pi x}\hat{\mathbf{y}}$

(C) $\mathbf{B} = \frac{\mu_0 I}{2\pi x}\left(1 + 2\sqrt{2}\right)\hat{\mathbf{y}}$

(D) $\mathbf{B} = \frac{\mu_0 I}{2\pi x}\hat{\mathbf{x}}$

(E) $\mathbf{B} = \frac{\mu_0 I}{2\pi x}\hat{\mathbf{y}}$

Problem 2:

A large, parallel-plate capacitor consists of two square plates that measure 0.5 m on each side. A charging current of 9 A is applied to the capacitor. Which of the following gives the approximate rate of change of the electric field between the plates?

(A) $2\ \frac{\text{V}}{\text{m}\cdot\text{s}}$

(B) $40\ \frac{\text{V}}{\text{m}\cdot\text{s}}$

(C) $1 \times 10^{12}\ \frac{\text{V}}{\text{m}\cdot\text{s}}$

(D) $4 \times 10^{12}\ \frac{\text{V}}{\text{m}\cdot\text{s}}$

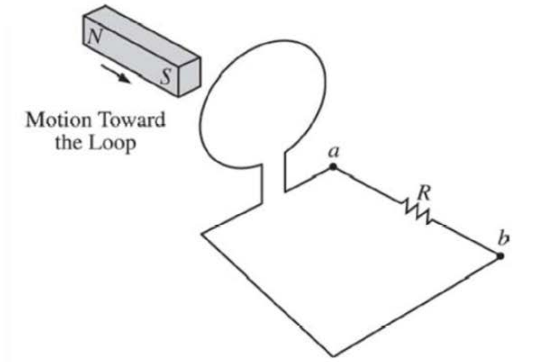
(E) $2 \times 10^{13}\ \frac{\text{V}}{\text{m}\cdot\text{s}}$

Problem 3:

Two nonrelativistic electrons move in circles under the influence of a uniform magnetic field $\mathbf{B}$. The ratio $r_1/r_2$ of the orbital radii is equal to 1/3. Which of the following is equal to the ratio $v_1/v_2$ of the speeds?

(A) 1/9
(B) 1/3
(C) 1
(D) 3
(E) 9

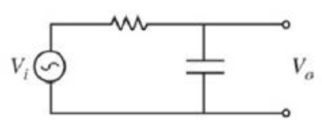
Problem 4:




The bar magnet shown in the figure above is moved completely through the loop. Which of the following is a true statement about the direction of the current flow between the two points $a$ and $b$ in the circuit?

(A) No current flows between $a$ and $b$ as the magnet passes through the loop.
(B) Current flows from $a$ to $b$ as the magnet passes through the loop.
(C) Current flows from $b$ to $a$ as the magnet passes through the loop.
(D) Current flows from $a$ to $b$ as the magnet enters the loop and from $b$ to $a$ as the magnet leaves the loop.
(E) Current flows from $b$ to $a$ as the magnet enters the loop and from $a$ to $b$ as the magnet leaves the loop.

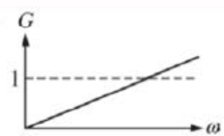
Problem 5:

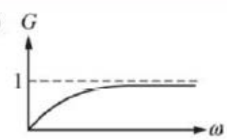


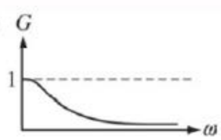

In the AC circuit, $V_i$ is the amplitude of the input voltage and $V_o$ is the amplitude of the output voltage. If the angular frequency $\omega$ of the input voltage is varied, which of the following gives the ratio $V_o/V_i = G$ as a function of $\omega$?

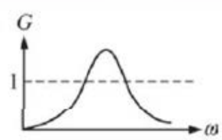
(A)



(B)



(C)


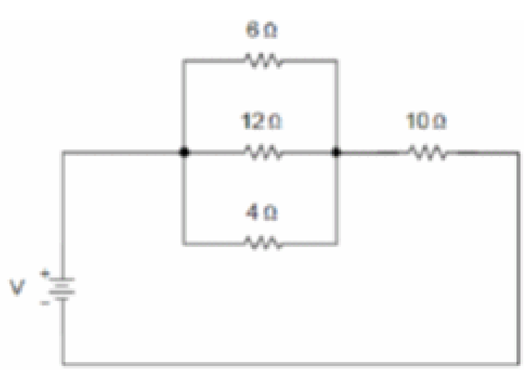

(D)



(E)


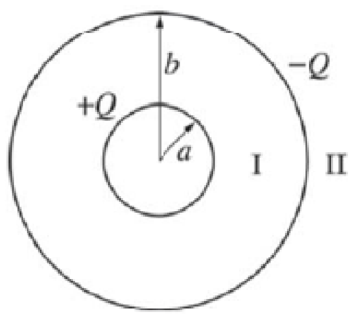

Problem 6:

The current in the 6-ohm resistor in the circuit shown is 0.5 ampere. The voltage V applied to the circuit is most nearly

(A) 6 V
(B) 8 V
(C) 16 V
(D) 18V
(E) 23 V



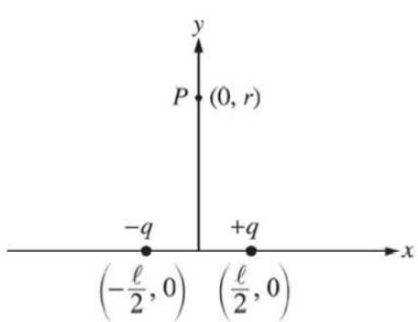
Problem 7:




Two thin, concentric, spherical conducting shells are arranged as shown in the figure. The inner shell has radius $a$, charge $+Q$, and is at zero electric potential. The outer shell has radius $b$ and charge $-Q$. If $r$ is the radial distance from the center of the spheres, what is the electric potential in region I $(a < r < b)$ and in region II $(r > b)$?

| | Region I | Region II |
|---|---|---|
| (A) | $\frac{Q}{4\pi\varepsilon_0}\frac{1}{r}$ | $0$ |
| (B) | $\frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r}-\frac{1}{a}\right)$ | $0$ |
| (C) | $\frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r}-\frac{1}{b}\right)$ | $-\frac{Q}{4\pi\varepsilon_0}\frac{1}{r}$ |
| (D) | $\frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r}-\frac{1}{a}\right)$ | $\frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{b}-\frac{1}{a}\right)$ |
| (E) | $\frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r}-\frac{1}{b}\right)$ | $\frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{a}-\frac{1}{b}\right)$ |

Problem 8:




A pair of electric charges of equal magnitude $q$ and opposite sign are separated by a distance $\ell$, as shown in the figure above. Which of the following gives the approximate magnitude and direction of the electric field set up by the two charges at a point $P$ on the $y$-axis, which is located a distance $r >> \ell$ from the $x$-axis?

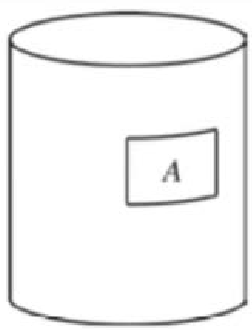
| | Magnitude | Direction |
|---|---|---|
| (A) | $\frac{1}{4\pi\epsilon_0}\frac{2q}{r^2}$ | $+y$ |
| (B) | $\frac{1}{4\pi\epsilon_0}\frac{2q}{r^2}$ | $+x$ |
| (C) | $\frac{1}{4\pi\epsilon_0}\frac{2q}{r^2}$ | $-x$ |
| (D) | $\frac{1}{4\pi\epsilon_0}\frac{q\ell}{r^3}$ | $+x$ |
| (E) | $\frac{1}{4\pi\epsilon_0}\frac{q\ell}{r^3}$ | $-x$ |

Problem 9:

In static electromagnetism, let $\mathbf{E}$, $\mathbf{B}$, $\mathbf{J}$, and $\rho$ be the electric field, magnetic field, current density, and charge density, respectively. Which of the following conditions allows the electric field to be written in the form $\mathbf{E} = -\nabla\phi$, where $\phi$ is the electrostatic potential?

(A) $\nabla \cdot \mathbf{J} = 0$
(B) $\nabla \cdot \mathbf{E} = \rho/\epsilon_0$
(C) $\nabla \times \mathbf{E} = \mathbf{0}$
(D) $\nabla \times \mathbf{B} = \mu_0\mathbf{J}$
(E) $\nabla \cdot \mathbf{B} = 0$

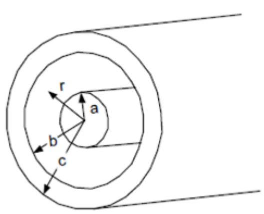
Problem 10:



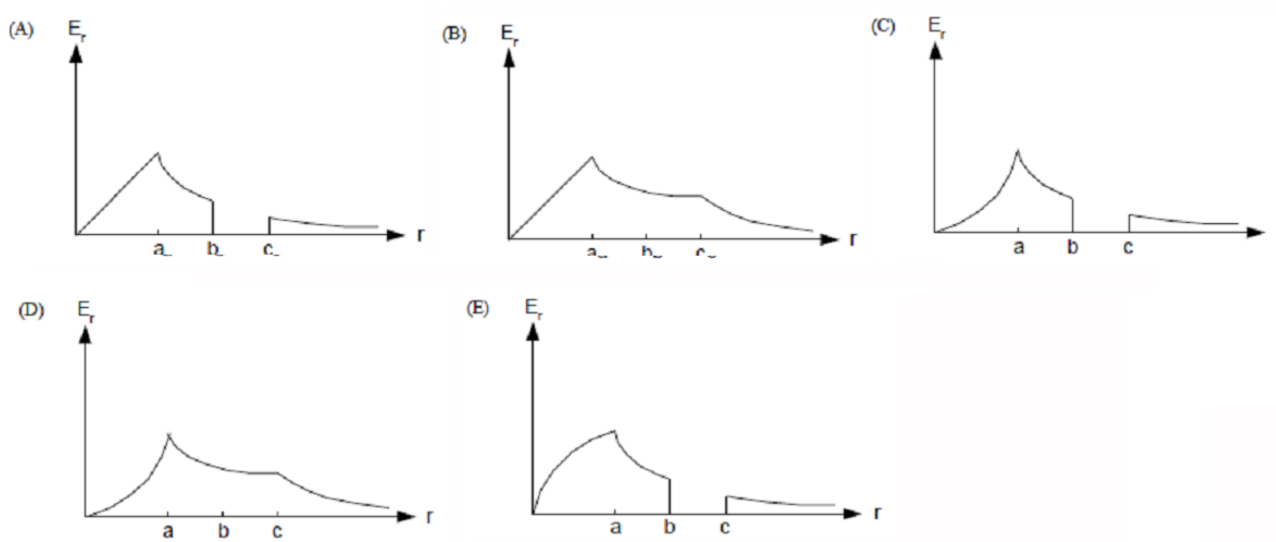

Consider the closed cylindrical Gaussian surface:. Suppose that the net charge enclosed within this surface is $+1 \times 10^{-9}$ C and the electric flux out through the portion of the surface marked $A$ is $-100$ N·m²/C. The flux through the rest of the surface is most nearly given by which of the following?

(A) $-100$ N·m²/C
(B) 0 N·m²/C
(C) 10 N·m²/C
(D) 100 N·m²/C
(E) 200 N·m²/C

Problem 11:



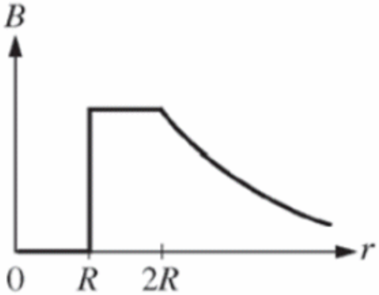

The Cylinder above has a uniform charge density ρ. It is surrounded by a concentric cylinderical shell, which is a conductor with inner and outer radii b and c, respectively. Which of the following graphs displays the radial electric field $E_r$ as a function of r, the distance from the axis?



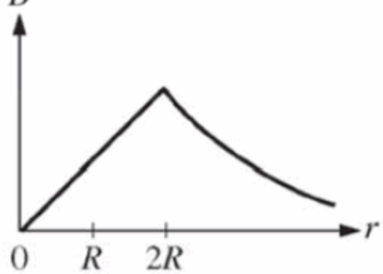
Problem 12:

A long, straight, hollow cylindrical wire with an inner radius $R$ and an outer radius $2R$ carries a uniform current density. Which of the following graphs best represents the magnitude of the magnetic field as a function of the distance from the center of the wire?

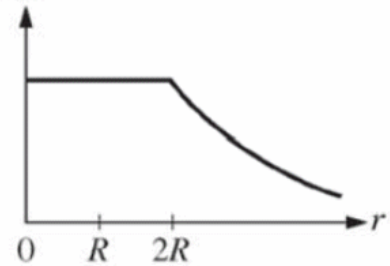
(A)



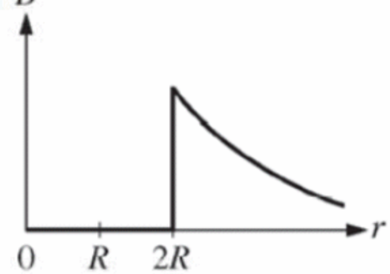

(B)



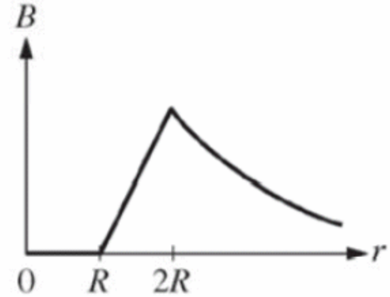

(C)




(D)




(E)




Problem 13:

Two infinite conducting planes are located at x = 0 and y = 0, respectively. These planes intersect each other at right angles along the z-axis. The planes are grounded. A point charge q is located at x = $a$ y = $a$. What is the magnitude of the force on the charge?

(A) $k \frac{3}{8}\frac{q^2}{a^2}$

(B) $k\left(\frac{1}{4}+\frac{\sqrt{2}}{8}\right)\frac{q^2}{a^2}$

(C) $k\left(\frac{1}{4}-\frac{\sqrt{2}}{8}\right)\frac{q^2}{a^2}$

(D) $k\left(\frac{\sqrt{2}}{4}+\frac{1}{8}\right)\frac{q^2}{a^2}$

(E) $k\left(\frac{\sqrt{2}}{4}-\frac{1}{8}\right)\frac{q^2}{a^2}$

Problem 14:

An ideal transformer has a primary coil of $N_p$ turns and a secondary coil of $N_s$ turns. An altering voltage $V_p$ is applied to the primary coil of the transformer. Which of the following statements is NOT correct?

(A) In the primary coil of the transformer, the voltage lags the current.

(B) The coefficient of mutual inductance between the primary and secondary coils is proportional to the product $N_pN_s$ .

(C) When the secondary coil is open, the power factor of the transformer is zero.

(D) When the secondary coil is open, the secondary voltage is $V_s = V_p(\frac{N_p}{N_s})$.

(E) If a resistance R is placed across the secondary coil, the reflected impedance at the terminals of the primary coil will be $Z_p = R(\frac{N_p}{N_s})^2$.

Problem 15:

A parallel-plate capacitor has plate separation $d$. The space between the plates is empty. A battery supplying voltage $V_0$ is connected across the capacitor, resulting in electromagnetic energy $U_0$ stored in the capacitor. A dielectric, of dielectric constant $\kappa$, is inserted so that it just fills the space between the plates. If the battery is still connected, what are the electric field $E$ and the energy $U$ stored in the dielectric, in terms of $V_0$ and $U_0$ ?

| | $E$ | $U$ |
|---|---|---|
| (A) | $\frac{V_0}{d}$ | $U_0$ |
| (B) | $\frac{V_0}{d}$ | $\kappa U_0$ |
| (C) | $\frac{V_0}{d}$ | $\kappa^2 U_0$ |
| (D) | $\frac{V_0}{\kappa d}$ | $U_0$ |
| (E) | $\frac{V_0}{\kappa d}$ | $\kappa U_0$ |