2, 1 Find the charge within a hemisphere of charge whose r_s, θ, ϕ ranges are: $r_0 \geqq r_s \geqq 0$, $\pi/2 \geqq \theta \geqq 0$, and $2\pi > \phi \geqq 0$. Let $r_0 = 0.02$ (m) and

(a) $\rho_v = \frac{3 \times 10^{-3}}{r_s^2} \cos^2 \phi$ (Cm^{-3});

(b) $\rho_v = \frac{3 \times 10^{-3} r_s^3 \cos \phi}{\sin \theta}$ (Cm^{-3})

2, 4 Find the force per unit length on two infinite and parallel lines of uniform and equal $\rho_\ell = 10(\mu$Cm$^{-1})$ but of opposite sign. Assume that the lines are separated d (m).

3-6. For $\bar{D} = (\hat{x}xy + \hat{y}2yz - \hat{z}5xy)$ (Cm^{-2}), find the number of flux lines that pass through a portion of the $z = 2$ plane for which $-3 \leqq x \leqq 3$, $0 \leqq y \leqq 2$.

3-7. Find the number of electric flux lines that emanate through a spherical surface of radius $r_s = b$ (m), $(a < b < c)$, centered at the origin, in a $\bar{D}$ field that has the following distribution: $\bar{D} = 0$, $0 \leqq r_s < a$; $\bar{D} = \hat{r}_s(10^2/r_s^2)$ (Cm^{-2}), $a < r_s < c$; $\bar{D} = 0$, $r_s > c$.

3-8. Through the use of Gauss's law, find the $\bar{D}$ and $\bar{E}$ inside and outside a 2 (m) radius spherical shell, centered at the origin, and possessing a $\rho_v = r_s$ (Cm^{-3}) charge distribution.

3-9. Through the use of Gauss's law, find the approximate values of $\bar{D}$ and $\bar{E}$ at points very near and very far from a disc of $\rho_s = (1 + r_c^2)$ (μCm^{-2}) in the $z = 0$ plane and of 1 (m) radius. Let the near point be (0, 0, 0.001) and the far point (0, 0, 100). Note that the disc appears as an infinite sheet to an observer at the point (0, 0, 0.001) and as a point charge when at the point (0, 0, 100).

4-1. An electron is released, at the origin, with zero initial velocity in an electric field $\bar{E} = \hat{x}8$ (Vm^{-1}). Find the expressions for the position, velocity, and acceleration of the electron.

4-2. A charge $Q = 8$ (μC) is moved by an external force in a field $\bar{E} = \hat{x}x + \hat{y}2y$. If the charge moves a distance $d\bar{\ell} = -\hat{x} + \hat{z}$ (μm), find the approximate energy exchanged and indicate if the energy is given to or taken from the $\bar{E}$ field.

4-3. An electron moves from an absolute potential location of 8 (V) to that of 5 (V). Find the energy exchanged and indicate if the energy is given to or taken from the $\bar{E}$ field.

4-4. Find the change in kinetic energy of a proton that falls from a potential of 2 (V) to -2 (V) and indicate if energy is given to or taken from the $\bar{E}$ field.

4-5. Find V_{ab} by integrating over the path ℓ' of Fig. 4-5 in an electric field $\bar{E} = -\hat{x}2yx - \hat{y}x^2$ when the points a and b are at (4, 6, 0) and (2, 2, 0), respectively.

4-6. Find the expression for V_{ab} about a point charge $Q = 4$ (μC), at the origin, with the reference at $r_b = 100$ (m).

4-7. The expression for V_{ab} about a point charge $Q = 2$ (μC), at the origin, gives 20 (V) at a radius of 30 (m). Where is the reference r_b?

4-8. Repeat Prob. 4-5 by integrating over the path ℓ of Fig. 4-5, a straight line from b to a. Is $\bar{E}$ a conservative field?

4-10. The potential difference V_{12} between $r_1 = 10$ (m) and $r_2 = 20$ (m) is found to be 50 (V). Find the absolute potential at $r_s = 50$ (m). Assume the potential field is due to a point charge at the origin.

4-11. Four point charges, $Q_1 = 2\,(\mu C)$, $Q_2 = -3\,(\mu C)$, $Q_3 = +2\,(\mu C)$, and $Q_4 = +1\,(\mu C)$ are located at points $P_1(0, 0, 0)$, $P_2(0, 0, 4)$, $P_3(0, 4, 4)$, and $P_4(0, 4, 0)$, respectively. Find the absolute potentials at: (a) $P(0, 2, 2)$; (b) $(0, 6, 0)$; (c) $(4, 2, 2)$.

4-12. For the electric dipole shown in Fig. 4-9(a), find the exact absolute potential along the $+z$ axis and compare with the approximate values obtained, using the expression assuming $r_s \gg d$ at the following points: (a) $P_1(0, 0, 0)$; (b) $P_2(0, 0, d/4)$; (c) $P_3(0, 0, 2d)$; (d) $P_4(0, 0, 10d)$. Assume $Q = 1\,(\mu C)$ and $d = 0.25$ (m).

4-13. Set up the integral, ready to integrate, to find the absolute potential at some general point (x, y, z) in free space due to a uniform $\rho_s = 2(x'^2 + y'^2)$, $-2 \leqq x' \leqq 2$, $-2 \leqq y' \leqq 2$, $z' = 0$. [Hint: Use the building block equation.]

4-14. Find the potential difference V_{ab} above an infinite sheet of uniform $\rho_s = 2\,(\mu \text{Cm}^{-2})$ located at $z = 0$ plane. Let $b = 20$ (m) and $a = 2$ (m).

4-15. Find the absolute potential along the axis of a disc in the $z = 0$ plane, and centered at the origin, when $\rho_s = 2r_c'^2\,(\text{Cm}^{-2})$, $0 \leqq r_c' \leqq b$. [Hint: Use the building block concept.]

4-16. The expression for the potential difference above an infinite sheet of uniform ρ_s, in the $z = 0$ plane and with reference at $z = 0$, is found to be $V_{z0} = -(3z/\epsilon_0)$ (V). Find: (a) $\bar{E}$ through the use of the gradient concept for $+z$; (b) ρ_s on the sheet.

4-17. A potential difference field is found to be $V = x^2 + y^2$. Find the $\bar{E}$ field.

4-18. Find $\bar{E}$, $\bar{D}$, and ρ_v for the following potential difference fields: (a) $V = 10x^2$; (b) $V = 2r_c \sin\phi$; (c) $V = (5/r_s)\cos\theta$.

4-19. For the electric dipole of Example E-11, find the exact expression for $\bar{E}$ at $r_s = 0$ and compare with results obtained by using (4.5-26).

4-20. From $\bar{E} = -\nabla V$, $\nabla \cdot \bar{D} = \rho_v$, and $\bar{D} = \epsilon_0 \bar{E}$, show that $\nabla^2 V = -\rho_v/\epsilon_0$, where $\nabla^2 \triangleq \nabla \cdot \nabla$ and is called the *Laplacian operator*. (See Sec. 1.12.)

4-21. The absolute potential in a given region due to a spherical charge distribution is equal to $(10^{-2}/\epsilon_0)r_s^2$ (V). Find $\bar{E}$, $\bar{D}$, ρ_v, and Q_{en} within a sphere of $r_s = 0.5$ (m).

4-22. For spherical charge distribution of radius $r_a = 2$ (m) and $\rho_v = 2r_s^2\,(\text{Cm}^{-3})$, find: (a) the absolute potential for $r_s \leqq r_a$; (b) the absolute potential for $r_s \geqq r_a$. Plot V for $0 \leqq r_s \leqq 4r_a$.

4-23. A thin spherical shell of radius r_a and uniform $\rho_s = 10^{-2}\,(\text{Cm}^{-2})$ is centered at the origin. If the total charge is $Q = 2$ (C), find: (a) r_a; (b) the absolute potential for $r_s \leqq r_a$; (c) the absolute potential for $r_s \geqq r_a$. Plot V for $0 \leqq r \leqq 4r_a$.

4-24. A coaxial cable, shown in Fig. 4-12, has $-\rho_\ell$ on the surface at r_a and $+\rho_\ell$ at the surface at r_b. Find: (a) the energy stored per meter length through the use of (4.6-16); (b) show that the result of (a) will reduce to $W_E = \frac{1}{2}\rho_\ell V_{ab}$; (c) the ρ_s at r_a; (d) the ρ_s at r_b.

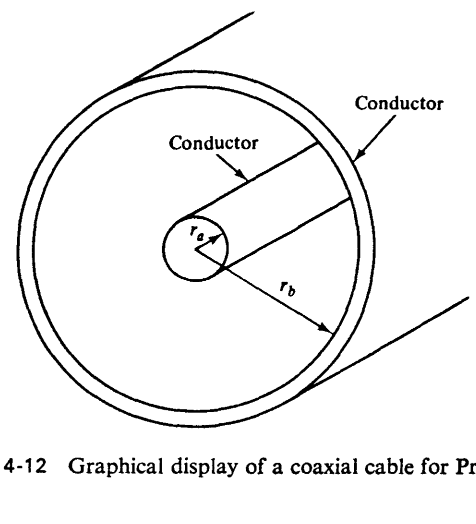


Figure 4-12 Graphical display of a coaxial cable for Prob. 4-24.

PROBLEM 5.4-1 Find the resistance of 100 feet of #12 gauge copper wire. The diameter of #12 gauge copper wire is 0.00205 (m).

PROBLEM 5.4-2 For the truncated copper wedge of Example E-5, find the resistance between the faces at $z = 0$ and $z = 1$ when: (a) $\bar{E} = \hat{z}2$; (b) $\bar{E} = \hat{z}4$; (c) $\bar{E} = \hat{z}K$ (constant)

PROBLEM 5.4-3 If the potential difference between the two conductor faces of Example E-5 turned out to equal $\pi/4$ (V), find $\bar{J}$ throughout the material.

PROBLEM 5.8-1 For the cube of Example E-9, find ρ_{sb} on all faces and ρ_{vb} inside the cube when: (a) $\bar{P} = \hat{x}x$ (Cm^{-2}); (b) $\bar{P} = \hat{x}(x^2 + 2)$ (Cm^{-2}) inside the cube.

PROBLEM 5.8-2 Find the total bound surface charge Q_{sb} and the total bound volume charge Q_{vb} for parts (a) and (b) of Prob. 5.8-1.

PROBLEM 5.9-1 In the region $y > 0$, we find $\epsilon_{r1} = 10$, and in the region $y < 0$, we find $\epsilon_{r2} = 4$. If $\bar{E}_1 = \hat{z}5$ (Vm^{-1}) at the boundary, find: (a) $\bar{D}_1$; (b) $\bar{E}_2$; (c) $\bar{D}_2$; (d) $\bar{P}_1$; (e) $\bar{P}_2$; (f) ρ_{sb}. Assume $\rho_s = 0$ at the boundary.

PROBLEM 5.9-2 A boundary between two dielectrics is found at the $x = 0$ plane. If #1 material exists for $x > 0$ with $\epsilon_{r1} = 4$ and #2 material exists for $x < 0$ with $\epsilon_{r2} = 5$, and when $\bar{E}_1 = (\hat{x}2 + \hat{y}3 - \hat{z}6)$ (at boundary), find: (a) $\bar{D}_1$; (b) $\bar{P}_1$; (c) $\bar{E}_2$; (d) $\bar{D}_2$; (e) $\bar{P}_2$; (f) ρ_{sb}. Assume $\rho_s = 0$ at the boundary.

PROBLEM 5.9-3 Repeat Prob. 5.9-1 for $\bar{E}_1 = \hat{y}5$ (Vm^{-1}).

PROBLEM 5.10-1 Show that the capacitance of two concentric metallic spheres separated by a dielectric, whose $\epsilon_r = 5$, equals $C = \dfrac{20\pi\epsilon_0}{(1/r_a) - (1/r_b)}$ (F). Let r_b be the inner radius of the outer sphere and r_a be the outer radius of the inner sphere.

PROBLEM 5.10-2 Find the expression for the capacitance per meter length of a cylindrical capacitor whose cross section is the same as that of the spherical configuration found in Fig. 5-15, with a conducting cylinder placed at the $r_c = a$ position, $a = 0.01$ (m), $b = 0.02$ (m), $c = 0.04$ (m), and $\epsilon_2 = 5\epsilon_0$.

PROBLEM 5.10-3 Find the capacitance of a parallel-plate capacitor whose plates are separated 1 (cm) and whose surface area equals 1 (cm)^2. Assume air dielectric and neglect $\bar{E}$ field fringing.

5-5. A hollow cylindrical conductor of uniform cross section has an outer radius of 2 (cm) and an inner radius of 1 (cm). Find the R of 10 (m) of this conductor when $\sigma = 5.0 \times 10^7$ (℧m^{-1}).

5-6. If the hollow cylindrical conductor of Prob. 5-5 is plated at the inner and outer radii, with a thin layer of $\sigma = \infty$ conducting material, find: (a) R between the outer and inner radii for a 1 (m) length of conductor; (b) the current that would flow from the inner to the outer surfaces for a 1 (m) length of conductor when a potential difference of 10^{-5} (V) exists between these surfaces.

5-7. A charge of 10^{-6} (C) is placed on a solid conducting sphere of 2 (m) radius and centered at the origin. Under static conditions find: (a) $\bar{E}$ inside the conductor; (b) ρ_s on the surface; (c) D_n just above the surface; (d) $\bar{E}$ for $r_s > 2$ (m).

5-8. An infinite length conducting cylinder of radius $r_c = 10^{-1}$ (m) is found along the z axis in free space. If $\bar{D} = \hat{r}_c 10^{-8}$ (Cm^{-2}) just off the conductor, find: (a) ρ_s; (b) ρ_ℓ; (c) $\bar{E}$ for $r_c > 10^{-1}$ (m).

5-9. A cylindrical test sample of germanium has a uniform radius $r_c = 2$ (mm) and a length of 3 (cm). If the ends are coated with a thin layer of high conductivity material and a voltage of 10 (V) is applied between the ends, find: (a) $\bar{E}$; (b) σ; (c) $\bar{J}$; (d) R, end to end; (e) I; (f) U_e; (g) U_h.

5-10. Calculate the σ of silicon, using (5.7-2) and parameters found in Table 5-2.

5-11. A thick spherical shell of dielectric is found centered at the origin with an outer radius of b (m) and an inner radius of a (m). If the dielectric constant is equal to 3 and the polarization vector

$$\bar{P} = \hat{r}_s \frac{10^{-5}}{r_s^2}\left(\frac{2}{3}\right) \quad (\text{Cm}^{-2})$$

find: (a) ρ_{sb} on both surfaces; (b) ρ_{vb} within the dielectric; (c) Q_{sb} on both surfaces; (d) Q_{vb}; (e) $Q_{b(\text{total})}$.

5-12. Repeat Example E-11 for a cylindrical configuration of the same dimensions, and display results in a manner similar to those found in Fig. 5-15.

5-13. In a sample of dielectric, it is found that $\bar{P} = \hat{z}/6\pi$ (pCm^{-2}) at a point where $\bar{E} = \hat{z}2$ (Vm^{-1}). Find: (a) χ_e; (b) ϵ_r; (c) ϵ; (d) $\bar{D}$.

5-14. Starting with Maxwell's first equation $\nabla \cdot \bar{D} = \rho_v$ (free charge density), show that Gauss's law in $\bar{D}$ becomes

$$\oint_s \bar{D} \cdot \overline{ds} = Q_{\text{en(free charge)}}$$

5-15. Starting with $\epsilon_0 \nabla \cdot \bar{E} = \rho_v + \rho_{vb}$, Eq. (5.8-3-16), show that Gauss's law in $\bar{E}$ becomes

$$\oint_s \bar{E} \cdot \overline{ds} = \frac{Q_{\text{en}} + Q_{\text{ben}}}{\epsilon_0}$$

where Q_{en} is the free charge enclosed and Q_{ben} is the total bound charge enclosed.

5-16. Show that at a dielectric-dielectric boundary

$$\hat{n}_{12} \cdot (\bar{P}_1 - \bar{P}_2) = -\rho_{sb(\text{total})} = P_{1n} - P_{2n}$$

5-17. Show that at a dielectric-dielectric boundary

$$\hat{n}_{12} \cdot (\bar{D}_1 - \bar{D}_2) = D_{1n} - D_{2n}$$

PROBLEM 6.4-1 Two infinite and parallel conducting planes are separated 0.02 (m), with one of the conductors in the $y = 0.2$ plane at $V = 50$ (V) and the other in the $y = 0.22$ plane at $V = 0$ (V). Assume $\rho_v = 0$ and $\epsilon = 5\epsilon_0$ between the conductors. Find: (a) V in the range $0.2 \leqq y \leqq 0.22$; (b) $\bar{E}$ between the conductors; (c) the capacitance per square meter.

PROBLEM 6.4-2 Two infinite length, concentric, and conducting cylinders of radii $r_a = 0.03$ (m) and $r_b = 0.06$ (m) are located with axes on the z axis. If $\epsilon = 5\epsilon_0$, $\rho_v = 0$ between the cylinders, $V = 100$ (V) at r_a, $V = 50$ (V) at r_b, find: (a) V in the range $0.03 \leqq r_c \leqq 0.06$; (b) $\bar{E}$; (c) $\bar{D}$; (d) ρ_s at r_b; (e) capacitance per meter length.

PROBLEM 6.4-3 Two infinite and radial planes are separated by a small gap along the z axis. One of the planes is in the $\phi = 0$ plane at $V = 100$ (V) while the other is in the $\phi = \pi/2$ plane at $V = 0$ (V). If $\epsilon = 2\epsilon_0$ and $\rho_v = 0$ between the planes, find: (a) V in the range $0 \leqq \phi \leqq \pi/2$; (b) $\bar{E}$; (c) $\bar{D}$; (d) ρ_s at $r_c = 2$ (m) on the plane at $\phi = \pi/2$.

PROBLEM 6.4-4 Solve for the constants A and B in (54) of Example E-8 and obtain: (a) eq. (55); (b) eq. (56); (c) expression for ρ_s on $\theta = \theta_1$, (constant) cone.

PROBLEM 6.4-5 Evaluate the constants A_1, A_2, A_3, and A_4 in eqs. (65), (66), (67), and (68) to obtain (69) and (70) of Example E-9, where two dielectric slabs are found between two conducting planes, as in Fig. 5-21.

PROBLEM 6.4-6 For the problem of Example E-9, using (58) and (60) show that: (a) $\bar{E}_1 = -\hat{z}A_1$; (b) $\bar{E}_2 = -\hat{z}A_3$; (c) $\rho_s|_{z=\ell} = \epsilon_2 A_3$; (d) $\rho_s|_{z=0} = -\epsilon_1 A_1$;

(e) $C = \epsilon_2 A_3 s/V_0 = \epsilon_2\epsilon_1 s/(\epsilon_2 \ell_1 + \epsilon_1 \ell_2)$, which can be placed in the form of $C = 1/\left(\frac{1}{C_1} + \frac{1}{C_2}\right)$, (5.10-14).

6-9. Two infinite length, concentric, and conducting cylinders of radii r_a and r_b are located on the z axis, as shown in Fig. 5-20. If $\epsilon = 5\epsilon_0$, $\rho_v = 0$ between the cylinders, $V = 0$ at r_a, and $|\bar{E}| = (-\partial V/\partial n) = 400\ (\text{Vm}^{-1})$ at r_b, solve Laplace's equation to find: (a) V; (b) $\bar{E}$; (c) ρ_s on both conductors. Note that this is an example of a mixed boundary-value problem formulation.

6-10. A two-conductor capacitor is formed in air by two conductors to resemble the wedge of Fig. 6-2. If the range on the cylindrical variables describing the capacitor are $0 \leqq \phi \leqq \pi/4$, $10^{-4} \leqq r_c \leqq 2$, $0 \leqq z \leqq 2$, find: (a) the approximate capacitance when zero field fringing is assumed; (b) the approximate ratio of ρ_s at $r_c = 10^{-4}$ to that at $r_c = 2$.

6-11. Find the capacitance of a two-conductor spherical capacitor formed by two concentric spheres of radii $r_b = 3$ (cm) and $r_a = 0.5$ (cm) when the region between the sphere is filled with a dielectric whose $\epsilon = 10\epsilon_0$.

6-12. The region between the two spheres of Prob. 6-11 is filled with a homogeneous conducting material whose $\sigma = 2\ (\mho\text{m}^{-1})$. When $V = 0$ at r_a and $V = 0.1$ (V) at r_b, find through the solution of Laplace's equation: (a) the potential field V; (b) $\bar{E}$; (c) the current between the two spheres.

6-13. A finite cone above a finite ground plane is formed by allowing $\theta_1 = \pi/4$ and $\theta_2 = \pi/2$ in Fig. 6-3. When the space between the cone and ground plane is filled with a homogeneous dielectric $\epsilon = 4\epsilon_0$ and $0 \leqq r_s \leqq 2$, find approximations for: (a) V; (b) $\bar{E}$; (c) ρ_s on both surfaces; (d) the capacitance between the cone and the ground plane.

6-14. Place two cylindrical and concentric regions of dielectric in the two-conductor cylindrical capacitor of Fig. 5-20. Let region #1 dielectric have an $\epsilon_1 = 2\epsilon_0$ within $r_a < r_c < r'$ and region #2 dielectric have an $\epsilon_2 = 4\epsilon_0$ within $r' < r_c < r_b$. If $V = 0$ at r_a and $V = V_0$ at r_b, find through the use of Laplace's equation: (a) the potential fields V_1 and V_2; (b) $\bar{E}_1$ and $\bar{E}_2$; (c) the capacitance of an ℓ meter length.

6-15. For the two-dimensional electrostatic problem shown in Fig. 6-7, find: (a) V field; (b) V at $y = 0$ and $z = b/2$ when $a = b$.

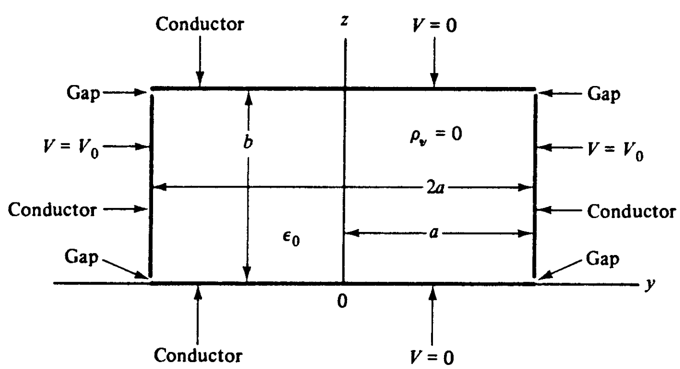


Figure 6-7 Graphical formulation of a two-variable electrostatic problem formed by four conductors of infinite extent in the x direction for Prob. 6-15.

6-16. For the two-dimensional electrostatic problem shown in Fig. 6-8, find the potential field V.

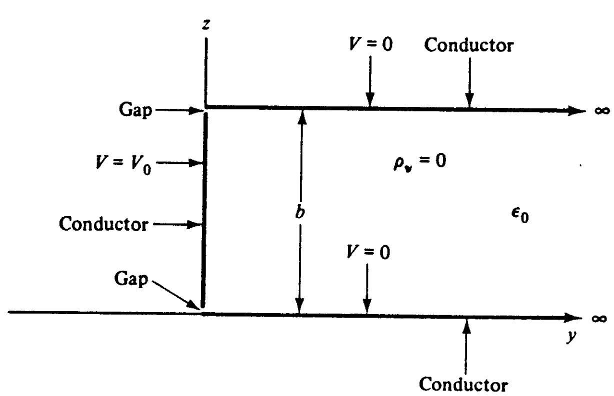


Figure 6-8 Graphical formulation of a two-variable electrostatic problem formed by three conductors for Prob. 6-16.

6-17. Discuss how the solution to Prob. 6-15 could be obtained through use of the results of Example E-10.

6-18. In all our solutions of Laplace's equation for the potential field, explain why the V solutions are independent of ϵ.

6-19. In the solution of Poisson's equation in Example E-11 for a thermionic diode, prove that Poisson's equation and the boundary conditions (6.6-2), (6.6-3), and (6.6-4) are satisfied.

6-20. From (5.2-4) and the results of Example E-11, obtain an expression for the electron velocity U in Example E-11.

PROBLEM 8.3-1 Through the use of (1), Fig. 8-3, and the results of Example 2-E-4, obtain (9) and (13).

PROBLEM 8.3-2 A current of 2 (A) flows in the configuration shown in Fig. 8-3. Find $\bar{H}$ at the rectangular point (4, 5, 0) when: (a) $a = -\infty$, $b = +\infty$; (b) $a = 0$, $b = \infty$; (c) $a = -2$, $b = +2$.

PROBLEM 8.3-3 If the circular current loop of Fig. 8-5 is shaped into a square current loop whose legs are a meters long and parallel to the axes, find: (a) the $\bar{H}$ field at the origin; (b) the $\bar{H}$ field along the $+z$ axis through the use of (14).

PROBLEM 8.3-4 Through the use of (1), Fig. 8-5, and the results of Example 2-E-6, obtain (16) and (19).

PROBLEM 8.3-5 A solenoid is 0.2 (m) long and has a radius of 0.005 (m). If it is closely wound and contains 1000 turns, find: (a) H at the center through the use of (21) and (22) and calculate the percent error; (b) H at the ends through the use of (23) and (24) and calculate the percent error.

8-15. Find the magnetic flux, due to a z-directed filamentary current I_0 of infinite extent, that flows through a rectangular cross section defined by $\phi = \pi/2$, $2 < r_c < 4$ (m), and $3 < z < 6$ (m).

8-16. From $\nabla \times \bar{E} = 0$ and $\nabla \times \nabla f = 0$, we found a scalar potential such that $\bar{E} = -\nabla V$. Now, if $\nabla \times \bar{H} = 0$ in a region where $\bar{J} = 0$, can we define a scalar magnetic potential such that $\bar{H} = -\nabla V_m$? Show the mathematical development.

8-17. For the filamentary circular current loop of Fig. 8-5, find: (a) the vector magnetic potential $\bar{A}$; (b) $\bar{B}$ through the use of $\bar{A}$.

8-18. Prove (8.10-4) through expansion of both sides.

8-19. Prove (8.10-5) by expansion of $\nabla(1/R)$ when

$$R = [(x - x')^2 + (y - y')^2 + (z - z')^2]^{1/2}$$

PROBLEM 9.9-1 If leg ℓ_3 of Fig. 9-21(a) and Example E-10 has an air gap of length $\ell_g = 2 \times 10^{-3}$ (m), find: (a) $\mathcal{R}$; (b) N to produce $B_g = 1$ (Wbm^{-2}) in the gap. Assume $H_s = 2000B_s$ and zero fringing at the gap.

PROBLEM 9.9-2 A toroidal magnetic circuit contains an air gap of length $\ell_g = 1.5 \times 10^{-3}$ (m). If the mean steel length $\ell_s = 0.3$ (m), the constant cross section $s = 6 \times 10^{-4}$ (m^2), and $NI = 1500$ (A turns), find the B_s in the steel. Assume silicon sheet steel (see Fig. 9-23) and zero fringing at the gap. [Hint: Assume B_s values and calculate required NI values with the aid of the magnetization curve. The correct B_s value will require an NI of 1500.]

PROBLEM 9.11-1 Obtain the expression for the self-inductance of the coaxial cable of Example E-13 through the use of (5) and (6).

PROBLEM 9.11-2 Find the force F exerted on the lower bar of the electromagnet of Fig. 9-26 when the reluctance of the ferromagnetic circuit is neglected and only the reluctance of the air gap is considered, $N = 1000$ turns, $I = 40$ (A), $s = 8 \times 10^{-4}$ (m^2), and $\ell_g = 2$ (mm).

9-10. A coaxial cable of cross section found in Fig. 5-2(a) is filled with a magnetic material whose $\mu_r = 150$. For $I = 5$ (A), $r_a = 0.01$ (m), and $r_b = 0.1$ (m), find: (a) $\bar{H}$, $\bar{B}$, and $\bar{M}$ within the magnetic material; (b) $\bar{J}_{sm}$ on the magnetic surfaces at r_a and r_b; (c) $\bar{J}_m$ within the magnetic material. Assume the inner conductor current in the $-z$ direction.

9-11. Solve Prob. 9-9 when the magnetic material is found only between the $z = 0$ plane and the $z = -0.01$ plane.

9-12. For the magnetic circuit of Example E-10, find B_s when $N = 300$ turns, $I = 0.05$ (A), and $H_s = 200B_s$ (Am^{-1}).

9-13. Find the flux in each of the legs of the magnetic circuit of Fig. 9-22(a) when $N = 500$, $I = 10$ (A), $\ell_1 = 0.3$ (m), $\ell_2 = 0.4$ (m), $\ell_3 = 0.1$ (m), $s_1 = s_2 = 10^{-3}$ (m^2), $s_3 = 1.5 \times 10^{-3}$ (m^2), and $H_s = 100B_s$.

9-14. For the magnetic circuit of Example E-10, find the self-inductance when $N = 4000$ (turns). Use the results of Example E-10.

9-15. A single layer of $N_2 = 200$ turns is wound directly on a long solenoid of $N_1 = 1000$ turns. Obtain the expression for the mutual inductance M_{12} when $\mu = \mu_0$, the radius of the inner solenoid is a (m), and its length is ℓ (m). Assume that all the flux of the inner solenoid links all the turns of the outer solenoid.

PROBLEM 10.4-1 Referring to Fig. 9.7(a), let the length of the bar between the conducting rails be ℓ, and let the velocity be $\bar{U}$ toward the right. In terms of $\bar{B}$, ℓ, $\bar{U}$, and R, determine: (a) the emf generated in the complete loop; (b) the power dissipated in R; and (c) the force required to move the bar.

PROBLEM 10.4-2 A rotating loop has been widely used as a means of measuring a magnetic field. A 4 (cm) × 8 (cm) rectangular loop of 50 turns is driven at 10,000 rpm by a small motor and the axis of rotation is oriented for maximum ac output from the loop. If the amplitude of the output voltage in air is 0.21 (mV), what is the ambient $\bar{H}$ field at that location?

PROBLEM 10.4-3 Referring to Fig. 9-7(a), let the length of the bar between the conducting rails be ℓ, and let the velocity be U_0. Find the emf if $|\bar{B}| = B_0 \sin \omega t$. Assume that R is a very high resistance such that the flux from the current is negligible.

10-3. A single-turn rotating loop having an area of 50 (cm^2) and a resistance of 5 (Ω) has its axis normal to a magnetic flux density of 1 (Wb/m^2). Find the average torque on the loop if the speed of rotation is 5000 rpm.

10-4. A 10 (cm) diameter single-turn circular conducting loop is spinning about an axis perpendicular to a magnetic field at a rate of 10,000 rpm. The short circuit current induced in the loop is 100 (A) rms. If the resistance of the loop is 0.1 (Ω), find: (a) the horsepower required to spin the loop; (b) the average torque on the loop. [1 (hp) = 746 (W).]

10-5. A transformer core is constructed of a permalloy having a saturation flux density of 0.75 (Wb/m^2). The primary is to be connected to $V = 20 \cos 2000\pi t$ (V). If the primary turns are not to exceed 1000, what is the minimum core cross-sectional area required?

PROBLEM 11.6-1 Calculate the skin depth of copper at 60 (Hz) and at 600 (KHz).

PROBLEM 11.6-2 Calculate the power loss per square meter of wall surface for a thick copper wall if the entering $\bar{E}$ field at the surface is 1 (V/m) at 500 (MHz).

PROBLEM 11.8-1 A plane wave is normally incident from air on a semi-infinite slab of dielectric material, $\epsilon_r' = 2.0$. If the frequency is 4 (GHz), find: (a) the reflection coefficient; (b) the standing wave ratio in front of the dielectric slab; (c) the wavelengths in air and in the slab; and (d) the percentage of the incident power that is reflected from the interface.

PROBLEM 11.8-2 Sketch the standing wave patterns for the E and H fields for Prob. 11.8-1, indicating the distances of the nearest maximum and minimum from the air-dielectric interface.

PROBLEM 11.8-4 Find the thickness and dielectric constant for an effective lens coating near the center of the optical frequency band Assume that $\epsilon'_{r_{glass}} = 2.34$, and that $\lambda_{air} = 4 \times 10^{-7}$ (m).

PROBLEM 11.8-5 Calculate the thickness for a "transparent" Plexiglass ($\epsilon_r' = 3.45$) radome for a radar operating at 10 (GHz).

11-1. An $\bar{E}$ field is given by $\bar{E} = \hat{z}50 \cos(10^9 t - 5x)$ (Vm^{-1}). Find (a) direction of wave travel; (b) velocity of the wave; (c) wavelength; and (d) complete description of the $\bar{H}$ field.

11-2. Write the expression for a sinusoidal plane wave having the $\bar{E}$ field polarized in the $+y$ direction, the $\bar{H}$ field polarized in the $-z$ direction, $f = 1$ (GHz), and $U = 10^8$ (m$\mathcal{A}^{-1}$).

11-3. An electric field is described by $\bar{E} = \hat{x}100 \cos(2\pi \times 10^8 t - 3y)$ (Vm^{-1}). Find (a) the power density in the wavefront; (b) the dielectric constant of the medium, assuming $\mu_r = 1$; and (c) the wavelength.

11-4. The average Poynting vector of an incident wave in air has a value of 10 (mW/cm^2). Find the rms values of the $\bar{E}$ and $\bar{H}$ fields.

11-5. Find the skin depth and velocity of propagation of an EM wave in sea water at 10 (kHz), 100 (kHz), 10 (MHz), and 1 (GHz) (see Prob. 11.5-1).

11-6. A plane wave at 24 (MHz), traveling through a lossy material, has a phase shift of 1 (rad/m) and its amplitude is reduced 50% for every meter traveled. Find α, β, U, and the skin depth. Also find the attenuation in dB/ft.

11-7. A plane wave in air has an electric field of 377 (Vm^{-1}). If the $\bar{E}$ field is polarized in the $+z$ direction and the $\bar{H}$ field in the $+y$ direction, find (a) the direction of power flow; (b) the average power density in the wavefront; (c) the average power density that would be reflected from a perfect dielectric having a dielectric constant of 4.

11-8. A plane wave is normally incident from a material ($\mu_r = 1, \epsilon_r = 1.5, \sigma = 0$) onto a material ($\mu_r = 1, \epsilon_r = 3, \sigma = 0$). Find (a) ρ; (b) S; (c) the total $\bar{E}$ field and total $\bar{H}$ field at the boundary in terms of the incident $\bar{E}$ and $\bar{H}$ fields.

11-9. At a dielectric-to-air interface, the incident $\mathcal{E}$ field is 100 (Vm^{-1}), the reflected $\mathcal{E}$ field (in phase with the incident $\mathcal{E}$ field) is 50 (Vm^{-1}), and the dielectric constant is 9. Find the amplitudes of the transmitted $\mathcal{E}$ and $\mathcal{H}$ fields.

11-10. If the distance between minima in a standing wave pattern in air is 1.0 (m), what is the frequency?

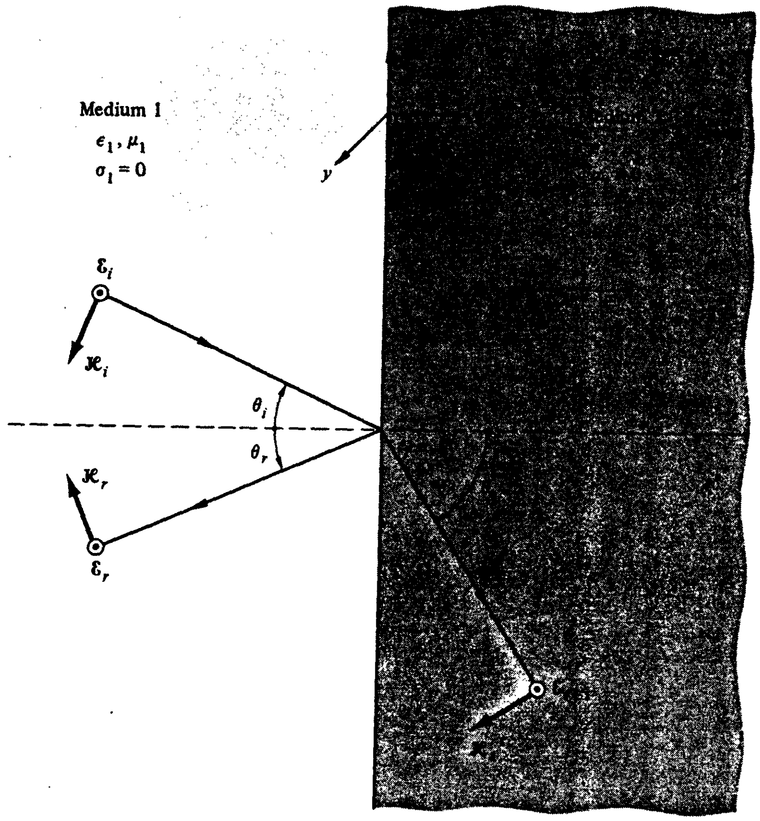
11-11. A standing wave pattern exists in front of a dielectric surface due to the reflection of a normally incident plane wave from air. If the standing wave ratio is 5, and a minimum of the $\bar{E}$ field exists at the interface, find the reflection coefficient.

11-12. The skin depth of a given conductor has been determined to be 1.0 (mm) at a frequency of 1000 (Hz). If the tangential electric field at the boundary between air and the conductor is 100 (Vm^{-1}), determine the amplitude and phase shift with respect to the boundary for a wave incident from air at a depth of 3 (mm) into the conductor.

11-13. A plane wave is normally incident on a conducting sheet. The frequency is 10 (GHz) and the skin depth is 0.001 (mm). What is the velocity of the wave in the conducting material?

6-28 In this chapter, the problem of reflection and transmission of uniform plane waves was considered in which the waves were incident-normal to the boundary between two media. It is also of interest to examine the reflection and transmission of uniform plane waves which are not normally incident. Consider Fig. P6-28 in which is shown a boundary between two lossless media and a uniform plane wave which is incident at an angle θ_i with respect to a perpendicular line

FIGURE P6-28



to that boundary. The incident electric field $\mathcal{E}_i$ is shown as perpendicular to the plane of incidence (xz plane). This is referred to as *perpendicular polarization.* The other possibility in which the incident electric field is parallel to the plane of incidence (parallel polarization) will be considered in the following problem. It should be clear that any arbitrary uniform plane wave can be resolved into two waves, one with parallel polarization and the other with perpendicular polarization. For the case of perpendicular polarization in Fig. P6-28, write vector expressions for all of the phasor fields $\hat{\mathbf{E}}_i$, $\hat{\mathbf{H}}_i$, $\hat{\mathbf{E}}_r$, $\hat{\mathbf{H}}_r$, $\hat{\mathbf{E}}_t$, $\hat{\mathbf{H}}_t$ in terms of the propagation constants, $\beta_1 = \omega\sqrt{\mu_1\epsilon_1}$ and $\beta_2 = \omega\sqrt{\mu_2\epsilon_2}$, the intrinsic impedances $\eta_1 = \sqrt{\mu_1/\epsilon_1}$ and $\eta_2 = \sqrt{\mu_2/\epsilon_2}$, and the angles θ_i, θ_r, θ_t. Determine relationships between θ_r and θ_i and between θ_t and θ_i (Snell's laws). Determine expressions for the reflection and transmission coefficients.

6-29 Repeat Prob. 6-28 for the case of parallel polarization where $\mathcal{E}_i$ is parallel to the plane of incidence. For this case determine an expression for the critical angle (Brewster angle) at which the incident wave is totally transmitted into the second medium.