

H. D. Young and R. A. Freedman, University Physics (12th Edition), Pearson (2008).

102/102E – Suggested Problems from the Textbook:

Ch21: 7,11, 29, 34, 38, 47, 55, 57, 89, 96.

Ch22: 4, 8, 22, 26, 28, 37, 41, 45, 46, 51.

Ch23: 1, 5, 9, 15, 19, 22, 34, 44, 50, 71, 76, 79, 81.

Ch24: 6, 12, 30, 32, 45, 49, 50, 57, 68, 77.

Ch25: 7, 12, 24, 30, 36, 47, 63, 68, 74, 80.

Ch26: 6, 13, 14, 23, 45, 47, 61, 62, 79, 92.

Ch27: 4, 12, 15, 27, 44, 69, 75, 77, 88, 91.

Ch28: 12, 19, 36, 37, 56, 59, 60, 76, 85, 87.

Ch29: 7, 25, 27, 28, 36, 45, 60, 61, 65, 77.

Ch30: 3, 11, 23, 43, 48, 49, 62, 63, 73.

Ch32: 5, 7, 8, 9, 13, 16, 40, 46, 47, 55.

Chapter 21

Problem 7,11, 29, 34, 38, 47, 55, 57, 89, 96.

Problem 21.7

Two small plastic spheres are given positive electrical charges. When they are 15.0 cm apart, the repulsive force between them has magnitude 0.220 N. What is the charge on each sphere (a) if the two charges are equal and (b) if one sphere has four times the charge of the other?

Problem 21.11

In an experiment in space, one proton is held fixed and another proton is released from rest a distance of 2.50 mm away. (a) What is the initial acceleration of the proton after it is released? (b) Sketch qualitative (no numbers!) acceleration-time and velocity-time graphs of the released proton's motion.

Problem 21.29

(a) What must the charge (sign and magnitude) of a 1.45-g particle be for it to remain stationary when placed in a downward-directed electric field of magnitude 650 N/C? (b) What is the magnitude of an electric field in which the electric force on a proton is equal in magnitude to its weight?

Problem 21.34

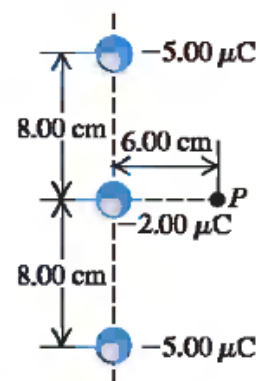
Point charge $q_1 = -5.00$ nC is at the origin and point charge $q_2 = +3.00$ nC is on the x-axis at $x = 3.00$ cm. Point P is on the y-axis at $y = 4.00$ cm. (a) Calculate the electric fields E_1 and E_2 at point P due to the charges q_1 and q_2 . Express your results in terms of unit vectors. (b) Use the results of part (a) to obtain the resultant field at P, expressed in unit vector form.

Problem 21.38

A uniform electric field exists in the region between two oppositely charged plane parallel plates. A proton is released from rest at the surface of the positively charged plate and strikes the surface of the opposite plate, 1.60 cm distant from the first, in a time interval of 1.50×10^{-6} s. (a) Find the magnitude of the electric field. (b) Find the speed of the proton when it strikes the negatively charged plate.

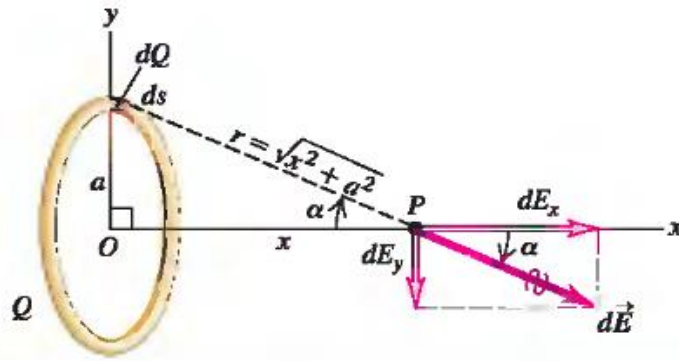
Problem 21.47

Three negative point charges lie along a line as shown in figure. Find the magnitude and direction of the electric field this combination of charges produces at point P, which lies 6.00 cm from the -2.00 μC charge measured perpendicular to the line connecting the three charges.



Problem 21.55

A ring-shaped conductor with radius $a = 2.50$ cm has a total positive charge $Q = +0.125$ nC uniformly distributed around it, as shown in figure. The center of the ring is at the origin of coordinates O. (a) What is the electric field (magnitude and direction) at point P, which is on the x-axis at $x = 40.0$ cm? (b) A point charge $q = -2.50$ μC is placed at the point P described in part (a). What are the magnitude and direction of the force exerted by the charge q on the ring?

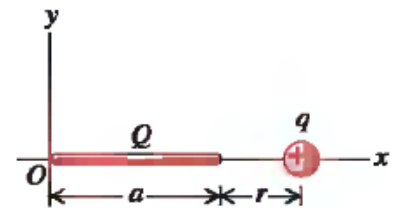


Problem 21.57

Two horizontal, infinite, plane sheets of charge are separated by a distance d . The lower sheet has negative charge with uniform surface charge density $-\sigma < 0$. The upper sheet has positive charge with uniform surface charge density $\sigma > 0$. What is the electric field (magnitude, and direction if the field is nonzero) (a) above the upper sheet, (b) below the lower sheet, (c) between the sheets?

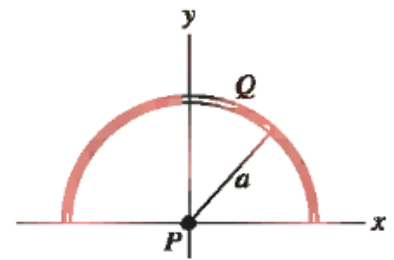
Problem 21.89

Positive charge Q is distributed uniformly along the x -axis from $x = 0$ to $x = a$. A positive point charge q is located on the positive x -axis at $x = a + r$, a distance r to the right of the end of Q (figure). (a) Calculate the x - and y -components of the electric field produced by the charge distribution Q at points on the positive x -axis where $x > a$. (b) Calculate the force (magnitude and direction) that the charge distribution Q exerts on q . (c) Show that if $r \gg a$, the magnitude of the force in part (b) is approximately $\frac{Qq}{4\pi\epsilon_0 r^2}$. Explain why this result is obtained.



Problem 21.96

Positive charge Q is uniformly distributed around a semi-circle of radius a (Figure). Find the electric field (magnitude and direction) at the center of curvature P .



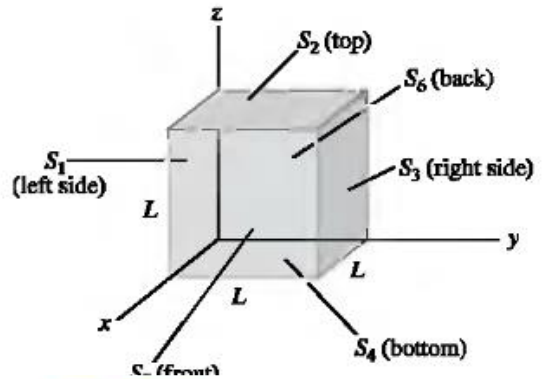
Chapter 22

Problem 4, 8, 22, 26, 28, 37, 41, 45, 46, 51.

Problem 22.4

A cube has sides of length $L = 0.30$ m. It is placed with one corner at the origin as shown in figure. The electric field is not uniform but is given by $\vec{E} = \left(-5.00 \frac{N}{C}\right) x \hat{i} + \left(3.00 \frac{N}{C}\right) z \hat{k}$

(a) Find the electric flux through each of the six cube faces $S_1, S_2, S_3, S_4, S_5,$ and S_6 . (b) Find the total electric charge inside the cube.



Problem 22.8

The three small spheres shown in figure carry charges $q_1 = 4.00$ nC, $q_2 = -7.80$ nC, and $q_3 = 2.40$ nC. Find the net electric flux through each of the following closed surfaces shown in cross section in the figure: (a) S_1 (b) S_2 (c) S_3 (d) S_4 (e) S_5 . (f) Do your answers to parts (a)-(e) depend on how the charge is distributed over each small sphere? Why or why not?



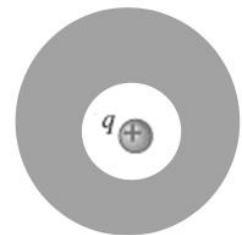
Surface	What it encloses
S_1	q_1
S_2	q_2
S_3	q_1 and q_2
S_4	q_1 and q_3
S_5	q_1 and q_2 and q_3

Problem 22.22

(a) At a distance of 0.200 cm from the center of a charged conducting sphere with radius 0.100 cm, the electric field is 480 N/c. What is the electric field 0.600 cm from the center of the sphere? (b) At a distance of 0.200 cm from the axis of a very long charged conducting cylinder with radius 0.100 cm, the electric field is 480 N/c. What is the electric field 0.600 cm from the axis of the cylinder? (c) At a distance of 0.200 cm from a large uniform sheet of charge, the electric field is 480 N/c. What is the electric field 1.20 cm from the sheet?

Problem 22.26

A conductor with an inner cavity, like that shown in figure, carries a total charge of + 5.00 nC. The charge within the cavity, insulated from the conductor, is -6.00 nC. How much charge is on (a) the inner surface of the conductor and (b) the outer surface of the conductor?



Problem 22.28

A square insulating sheet 80.0 cm on a side is held horizontally. The sheet has 7.50 nC of charge spread uniformly over its area. (a) Calculate the electric field at a point 0.100 mm above the center of the sheet. (b) Estimate the electric field at a point 100 m above the center of the sheet. (c) Would the answers to parts (a) and (b) be different if the sheet were made of a conducting material? Why or why not?

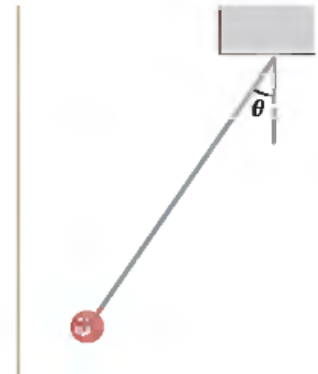
Problem 22.37

The Coaxial Cable: A long coaxial cable consists of an inner cylindrical conductor with radius a and an outer coaxial cylinder with inner radius b and outer radius c . The outer cylinder is mounted on

insulating supports and has no net charge. The inner cylinder has a uniform positive charge per unit length λ . Calculate the electric field (a) at any point between the cylinders a distance r from the axis and (b) at any point outside the outer cylinder. (c) Graph the magnitude of the electric field as a function of the distance r from the axis of the cable, from $r = 0$ to $r = 2c$. (d) Find the charge per unit length on the inner surface and on the outer surface of the outer cylinder.

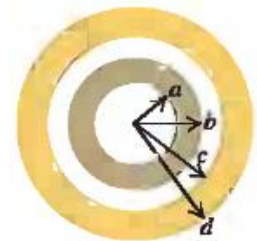
Problem 22.41

A small sphere with a mass figure of 0.002 g and carrying a charge of 5.00×10^{-8} C hangs from a thread near a very large, charged conducting sheet, as shown in figure. The charge density on the sheet is 2.50×10^{-9} C/m². Find the angle of the thread.



Problem 22.45

Concentric Spherical Shells. A small conducting spherical shell with inner radius a and outer radius b is concentric with a larger conducting spherical shell with inner radius c and outer radius d (figure). The inner shell has total charge $+2q$, and the outer shell has charge $+4q$. (a) Calculate the electric field (magnitude and direction) in terms of q and the distance r from the , common center of the two shells for: (i) $r < a$; (ii) $a < r < b$; (iii) $b < r < c$; (iv) $c < r < d$; (v) $r > d$. Show your results in a graph of the radial component of \vec{E} as a function of r . (b) What is the total charge on the (i) inner surface of the small shell; (ii) outer surface of the small shell; (iii) inner surface of the large shell; (iv) outer surface of the large?



Problem 22.46

Repeat Problem 22.45, but now let the outer shell have charge $-2q$. As in Problem 22.45, the inner shell has charge $+2q$.

Problem 22.51.

A single isolated, large conducting plate (figure) has a charge per unit area σ on its surface. Because the plate is a conductor, the electric field at its surface is perpendicular to the surface and has magnitude $|\vec{E}| = \frac{\sigma}{\epsilon_0}$ (a) In Example 22.7 (Section 22.4) it was shown that the field caused by a large, uniformly charged sheet with charge per unit area σ has magnitude $|\vec{E}| = \frac{\sigma}{2\epsilon_0}$, exactly half as much as for a charged conducting plate. Why is there a difference? (b) Regarding the charge distribution on the conducting plate as being two sheets of charge (one on each surface), each with charge per unit area σ , use the result of Example 22.7 and the principle of superposition to show that $|\vec{E}| = 0$ inside the plate and $|\vec{E}| = \frac{\sigma}{\epsilon_0}$ outside the plate.

Chapter 23

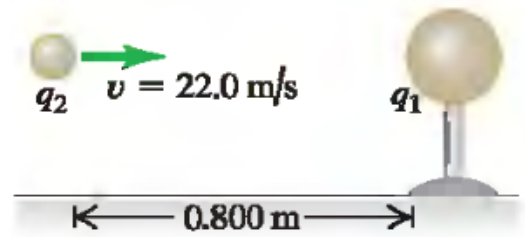
Problem 1, 5, 9, 15, 19, 22, 34, 44, 50, 71, 76, 79, 81.

Problem 1

A point charge $q_1 = +2.40 \mu\text{C}$ is held stationary at the origin. A second point charge $q_2 = -4.30 \mu\text{C}$ moves from the point $x = 0.150 \text{ m}$, $y = 0$ to the point $x = 0.250 \text{ m}$, $y = 0.250 \text{ m}$. How much work is done by the electric force on q_2 ?

Problem 5

A small metal sphere, carrying a net charge of $q_1 = -2.80 \mu\text{C}$, is held in a stationary position by insulating supports. A second small metal sphere, with a net charge of $q_2 = -7.80 \mu\text{C}$ and mass 1.50 g , is projected toward q_1 . When the two spheres are 0.800 m apart, q_2 is moving toward q_1 with speed 22.0 m/s . Assume that the two spheres can be treated as point charges. You can ignore the force of gravity.



- (a) What is the speed of q_2 when the spheres are 0.400 m apart?
- (b) How close does q_2 get to q_1 ?

Problem 9

A point charge $q_1 = 4.00 \text{ nC}$ is placed at the origin, and a second point charge $q_2 = -3.00 \text{ nC}$ is placed on the x -axis at $x = +20.0 \text{ cm}$. A third point charge $q_3 = 2.00 \text{ nC}$ is to be placed on the x -axis between q_1 and q_2 . (Take as zero the potential energy of the three charges when they are infinitely far apart.) (a) What is the potential energy of the system of the three charges if q_3 is placed at $x = +10.0 \text{ cm}$? (b) Where should q_3 be placed to make the potential energy of the system equal to zero?

Problem 15

A small particle has charge $-5.00 \mu\text{C}$ and mass $2.00 \times 10^{-4} \text{ kg}$. It moves from point A, where the electric potential is $V_A = +200 \text{ V}$, to point B, where the electric potential is $V_B = +800 \text{ V}$. The electric force is the only force acting on the particle. The particle has speed 5.00 m/s at point A. What is its speed at point B? Is it moving faster or slower at B than at A? Explain.

Problem 19

A point charge has a charge of $2.50 \times 10^{-11} \text{ C}$. At what distance from the point charge is the electric potential (a) 90.0 V and (b) 30.0 V ? Take the potential to be zero at an infinite distance from the charge.

Problem 22

Two positive point charges, each of magnitude q , are fixed on the y -axis at the points $y = +a$ and $y = -a$. Take the potential to be zero at an infinite distance from the charges. (a) Show the positions of the charges in a diagram. (b) What is the potential V_0 at the origin? (c) Show that the potential at

any point on the x -axis is;
$$V = \frac{2q}{4\pi\epsilon_0\sqrt{a^2+x^2}}$$

Problem 34

An infinitely long line of charge has linear charge density $\lambda = 5.00 \times 10^{-12} \text{ C/m}$. A proton (mass $1.67 \times 10^{-27} \text{ kg}$, charge $+1.60 \times 10^{-19} \text{ C}$) is 18.0 cm from the line and moving directly toward the line at $1.50 \times 10^3 \text{ m/s}$. (a) Calculate the proton's initial kinetic energy. (b) How close does the proton get to the line of charge?

Problem 44

The electric field at the surface of a charged, solid, copper sphere with radius 0.200 m is 3800 N/C , directed toward the center of the sphere. What is the potential at the center of the sphere, if we take the potential to be zero infinitely far from the sphere?

Problem 50

A metal sphere with radius $r_a = 1.20 \text{ cm}$ is supported on an insulating stand at the center of a hollow, metal, spherical shell with radius $r_b = 9.60 \text{ cm}$. Charge $+q$ is put on the inner sphere and charge $-q$ on the outer spherical shell. The magnitude of q is chosen to make the potential difference between the spheres 500 V , with the inner sphere at higher potential (a) Use the result of Exercise 23.49(b) to calculate q . (b) With the help of the result of Exercise 23.49(a), sketch the equipotential surfaces that correspond to 500 , 400 , 300 , 200 , 100 , and 0 V . (c) In your sketch, show the electric field lines. Are the electric field lines and equipotential surfaces mutually perpendicular? Are the equipotential surfaces closer together when the magnitude of E is largest?

Problem 71

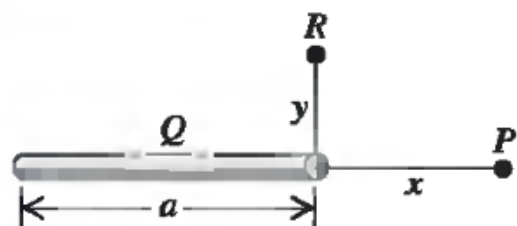
Self-Energy of a Sphere of Charge. A solid sphere of radius R contains a total charge Q distributed uniformly throughout its volume. Find the energy needed to assemble this charge by bringing infinitesimal charges from far away. This energy is called the "self-energy" of the charge distribution. (Hint: After you have assembled a charge q in a sphere of radius r , how much energy would it take to add a spherical shell of thickness dr having charge dq ? Then integrate to get the total energy.)

Problem 76

Two plastic spheres, each carrying charge uniformly distributed throughout its interior, are initially placed in contact and then released. One sphere is 60.0 cm in diameter, has mass 50.0 g and contains $-10.0 \mu\text{C}$ of charge. The other sphere is 40.0 cm in diameter, has mass 150.0 g , and contains $-30.0 \mu\text{C}$ of charge. Find the maximum acceleration and the maximum speed achieved by each sphere (relative to the fixed point of their initial location in space), assuming that no other forces are acting on them. (Hint: The uniformly distributed charges behave as though they were concentrated at the centers of the two spheres.)

Problem 79

Electric charge is distributed uniformly along a thin rod of length a , with total charge Q . Take the potential to be zero at infinity. Find the potential at the following points: (a) point P , a distance x to the right of the rod, and (b) point R , a distance y above the right-hand end of the rod. (c) In parts (a) and (b), what does your result reduce to as x or y becomes much larger than a ?



Problem 81

Two metal spheres of different sizes are charged such that the electric potential is the same at the surface of each. Sphere A has a radius three times that of sphere B. Let Q_A and Q_B be the charges on the two spheres, and let E_A and E_B be the electric-field magnitudes at the surfaces of the two spheres. What are (a) the ratio Q_B / Q_A and (b) the ratio E_B / E_A ?

Chapter 24

Problem 6, 12, 30, 32, 45, 49, 50, 57, 68, 77

Problem 6

A $10.0\ \mu\text{F}$ parallel-plate capacitor is connected to a $12.0\ \text{V}$ battery. After the capacitor is fully charged, the battery is disconnected without loss of any of the charge on the plates. (a) A voltmeter is connected across the two plates without discharging them. What does it read? (b) What would the voltmeter read if (i) the plate separation were doubled; (ii) the radius of each plate were doubled and, but their separation was unchanged?

Problem 12

A spherical capacitor is formed from two concentric, spherical, conducting shells separated by vacuum. The inner sphere has radius $15.0\ \text{cm}$ and the capacitance is $116\ \text{pF}$. (a) What is the radius of the outer sphere? (b) If the potential difference between the two spheres is $220\ \text{V}$, what is the magnitude of charge on each sphere?

Problem 30

A parallel-plate vacuum capacitor has $8.38\ \text{J}$ of energy stored in it. The separation between the plates is $230\ \text{mm}$. If the separation is decreased to $1.15\ \text{mm}$, what is the energy stored (a) if the capacitor is disconnected from the potential source so the charge on the plates remains constant, and (b) if the capacitor remains connected to the potential source so the potential difference between the plates remains constant?

Problem 32

For the capacitor network shown in figure, the potential difference across ab is $36\ \text{V}$. Find (a) the total charge stored in this network; (b) the charge on each capacitor; (c) the total energy stored in the network; (d) the energy stored in each capacitor; (e) the potential differences across each capacitor.



Problem 45

When a $360\ \text{nF}$ air capacitor ($1\ \text{nF} = 10^{-9}\ \text{F}$) is connected to a power supply, the energy stored in the capacitor is $1.85 \times 10^{-5}\ \text{J}$. While the capacitor is kept connected to the power supply, a slab of dielectric is inserted that completely fills the space between the plates. This increases the stored energy by $2.32 \times 10^{-5}\ \text{J}$.

- What is the potential difference between the capacitor plates?
- What is the dielectric constant of the slab?

Problem 49

A parallel-plate capacitor has the volume between its plates filled with plastic with dielectric constant K . The magnitude of the charge on each plate is Q . Each plate has area A , and the distance between the plates is d . (a) Use Gauss's law to calculate the magnitude of the electric field in the dielectric. (b) Use the electric field determined in part (a) to calculate the potential difference between the two plates. (c) Use the result of part (b) to determine the capacitance of the capacitor. Compare your result to Equation 24.12

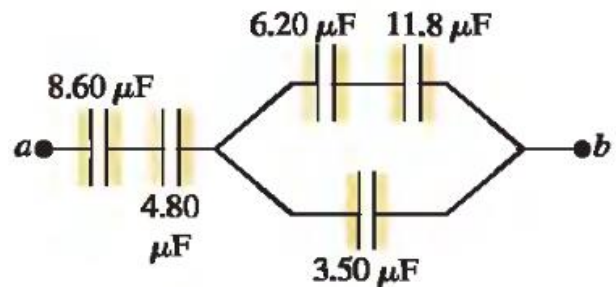
$$K = C/C_0$$

Problem 50

A parallel-plate air capacitor is made by using two plates 16 cm^2 , spaced 4.7 mm apart. It is connected to a 12 V battery. (a) What is the capacitance? (b) What is the charge on each plate? (c) What is the electric field between the plates? (d) What is the energy stored in the capacitor? (e) If the battery is disconnected and then the plates are pulled apart to a separation of 9.4 mm , what are the answers to parts (a)-(d)?

Problem 57

For the capacitor network shown in figure, the potential difference across ab is 12.0 V . Find (a) the total energy stored in this network and (b) the energy stored in the $4.80 \mu\text{F}$ capacitor.



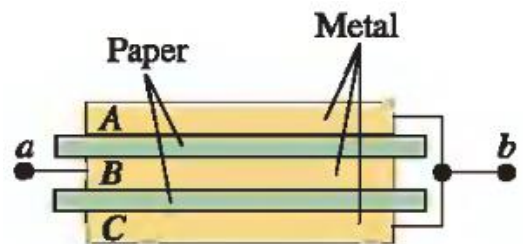
Problem 68

A solid conducting sphere of radius R carries a charge Q . Calculate the electric-field energy density at a point a distance r from the center of the sphere for (a) $r < R$ and (b) $r > R$. (c) Calculate the total electric-field energy associated with the charged sphere. (Hint: Consider a spherical shell of radius r and thickness dr that has volume $dV = 4\pi r^2 dr$, and find the energy stored in this volume. Then integrate from $r = 0$ to $r \rightarrow \infty$) (d) Explain why the result of part (c) can be interpreted as the amount of work required to assemble the charge Q on the sphere. (e) By using Eq. (24.9)

$\{U = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} CV^2 = \frac{1}{2} QV\}$ and the result of part (c), show that the capacitance of the sphere is as given in as $C = Q/V_{ab}$

Problem 77

Three square metal plates A, B, and C, each 12.0 cm on a side and 1.50 mm thick, are arranged as in figure. The plates are separated by sheets of paper 0.45 mm thick and with dielectric constant 4.2 . The outer plates are connected together and connected to point b . The inner plate is connected to point a .



- (a) Copy the diagram and show by plus and minus signs the charge distribution on the plates when point a is maintained at a positive potential relative to point b .
- (b) What is the capacitance between points a and b ?

Chapter 25

Problem 7, 12, 24, 30, 36, 47, 63, 68, 74, 80

Problem 7

The current in a wire varies with time according to the relationship $I = 55 \text{ A} - (0.65 \text{ A/s}^2)t^2$.

- (a) How many coulombs of charge pass a cross section of the wire in the time interval between $t = 0$ and $t = 8.0 \text{ s}$?
- (b) What constant current would transport the same charge in the same time interval?

Problem 12

A copper wire has a square cross section 2.3 mm on a side. The wire is 4.0 m long and carries a current of 3.6 A . The density of free electrons is $8.5 \times 10^{28} / \text{m}^3$. Find the magnitudes of

- (a) the current density in the wire and
- (b) the electric field in the wire.
- (c) How much time is required for an electron to travel the length of the wire?

Problem 24

You apply a potential difference of 4.50 V between the ends of a wire that is 2.50 m in length and 0.654 mm in radius. The resulting current through the wire is 17.6 A . What is the resistivity of the wire?

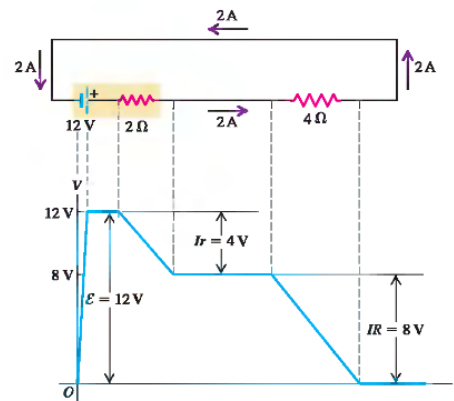
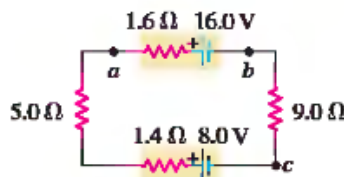
Problem 30

A hollow aluminum cylinder is 2.50 m long and has an inner radius of 3.20 cm and an outer radius of 4.60 cm . Treat each surface (inner, outer, and the two end faces) as an equipotential surface. At room temperature, what will an ohmmeter read if it is connected between

- (a) the opposite faces and
- (b) the inner and outer surfaces?

Problem 36

The circuit shown in Figure contains two batteries, each with an emf and an internal resistance, and two resistors. Find (a) the current in the circuit (magnitude and direction); (b) the terminal voltage V_{ab} of the 16.0V battery; (c) the potential difference V_{oc} of point a with respect to point c. (d) Using Figure on right as a model, Graph the potential rises and drops in this circuit.



Problem 47

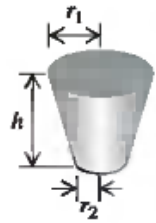
Consider a resistor with length L , uniform cross-sectional area A , and uniform resistivity ρ that is carrying a current with uniform current density J . Use

$$P = V_{ab}I = I^2R = \frac{V_{ab}^2}{R}$$

to find the electrical power dissipated per unit volume, p . Express your result in terms of (a) E and J ; (b) J and ρ ; (c) E and ρ .

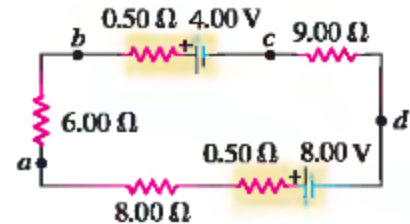
Problem 63

A material of resistivity ρ is formed into a solid, truncated cone of height h and radii r_1 and r_2 at either end (see Figure). (a) Calculate the resistance of the cone between the two flat end faces. (Hint: Imagine slicing the cone into very many thin disks, and calculate the resistance of one such disk.) (b) Show that your result agrees with Eq. $\{R = \frac{\rho L}{A}\}$ when $r_1 = r_2$.



Problem 68

(a) What is the potential difference V_{ad} in the circuit of Figure 2? (b) What is the terminal voltage of the 4.00-V battery? (c) A battery with emf 10.30 V and internal resistance 0.50Ω is inserted in the circuit at d , with its negative terminal connected to the negative terminal of the 8.00-V battery. What is the difference of potential V_{be} between the terminal of the 4.00-V battery now?



Problem 74

A cylindrical copper cable 1.50 km long is connected across a 220.0-V potential difference. (a) What should be its diameter so that it produces heat at a rate of 50.0 W? (b) What is the electric field inside the cable under these conditions?

Problem 80

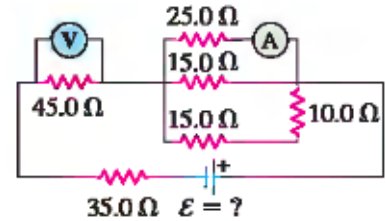
A lightning bolt strikes one end of a steel lightning rod, producing a 15,000 A current burst that lasts for $65 \mu s$. The rod is 20 m long and 1.8 cm in diameter, and its other end is connected to the ground by 35 m of 8.0 mm-diameter copper wire. (a) Find the potential difference between the top of the steel rod and the lower end of the copper wire during the current burst. (b) Find the total energy deposited in the rod and wire by the current burst.

Chapter 26

Problem 6, 13, 14, 23, 45, 47, 61, 62, 79, 92

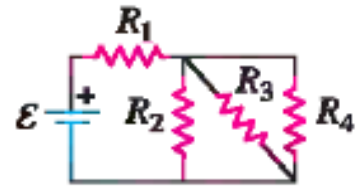
Problem 6

For the circuit shown in figure, both meters are idealized, the battery has no appreciable internal resistance, and the ammeter reads 1.25 A (a) What does the voltmeter read? (b) What is the emf \mathcal{E} of the battery?



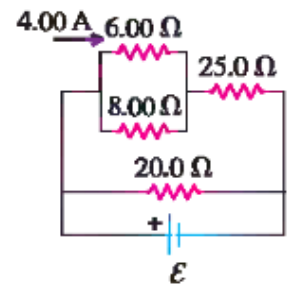
Problem 13

In the circuit of figure., each resistor represents a light bulb. Let $R_1 = R_2 = R_3 = R_4 = 4.50 \Omega$ and $\mathcal{E} = 9.00 \text{ V}$. (a) Find the current in each bulb. (b) Find the power dissipated in each bulb. Which bulb or bulbs glow the brightest? (c) Bulb R_4 is now removed from the circuit, leaving a break in the wire at its position. Now what is the current in each of the remaining bulbs $R_1, R_2,$ and R_3 ? (d) With bulb R_4 removed, what is the power dissipated in each of the remaining bulbs? (e) Which light bulb(s) glow brighter as a result of removing R_4 ? Which bulb(s) glow less brightly! Discuss why there are different effects on different bulbs.



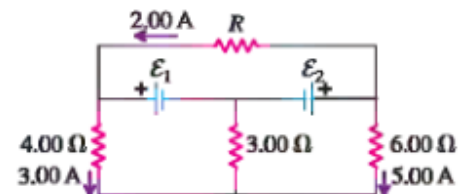
Problem 14

Consider the circuit shown in figure. The current through the 6.00Ω resistor is 4.00 A , in the direction shown. What are the currents through the 25.0Ω and 20.0Ω resistors?



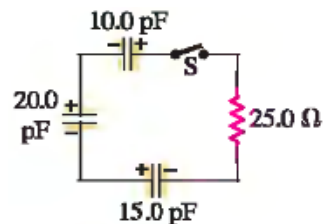
Problem 23

In the circuit shown in figure, find (a) the current in the 3.00Ω resistor; (b) the unknown emfs $\mathcal{E}_1,$ and \mathcal{E}_2 (c) the resistance R . Note that three currents are given.



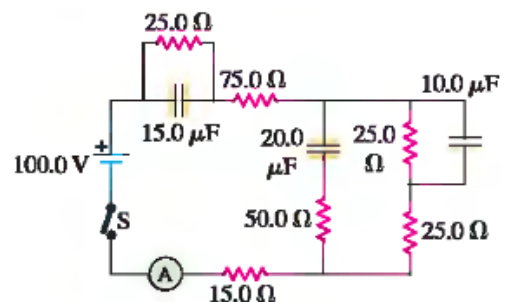
Problem 45

In the circuit shown in figure each capacitor initially has a charge of magnitude 3.50 nC on its plates. After the switch S is closed, what will be the current in the circuit at the instant that the capacitors have lost 80.0% of their initial stored energy?



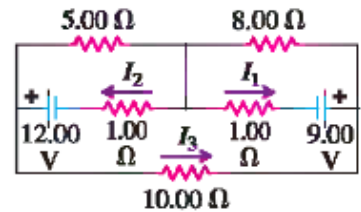
Problem 47

In the circuit in figure the capacitors are all initially uncharged, the battery has no internal resistance, and the ammeter is idealized. Find the reading of the ammeter. (a) just after the switch S is closed and (b) after the switch has been closed for a very long time



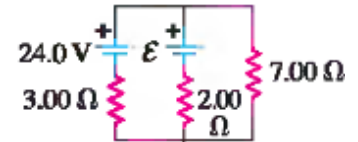
Problem 61

Calculate the three currents I_1 , I_2 , and I_3 indicated in the circuit diagram shown in figure.



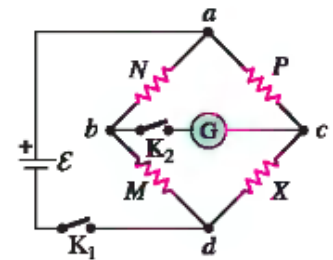
Problem 62

What must the emf ε in figure be in order for the current through the 7.00Ω resistor to be 1.80 A ? Each emf source has negligible internal resistance.



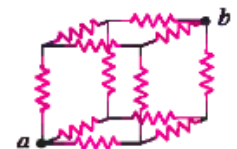
Problem 79

The Wheatstone Bridge: The circuit shown in figure called a *Wheatstone bridge*, is used to determine the value of an unknown resistor X by comparison with three resistors M , N , and P whose resistances can be varied. For each setting, the resistance of each resistor is precisely known. With switches K_1 and K_2 closed, these resistors are varied until the current in the galvanometer G is zero; the bridge is then said to be balanced. (a) Show that under this condition the unknown resistance is given by $X = MP/N$. (This method permits very high precision in comparing resistors.) (b) If the galvanometer G shows zero deflection when $M = 850.0 \Omega$, $N = 15.0 \Omega$, and $P = 33.48 \Omega$, what is the unknown resistor X ?



Problem 92

Suppose a resistor R lies along each edge of a cube (12 resistors all) with connections at the corners. Find the equivalent resistance between two diagonally opposite corners of the cube (points a and b in figure).



Chapter 27

Problem 4, 12, 15, 27, 44, 69, 75, 77, 88, 91

Problem 4

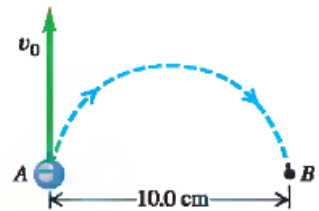
A particle with mass $1.81 \cdot 10^{-3} \text{ kg}$ and a charge of $1.22 \cdot 10^{-8} \text{ C}$ has, at a given instant, a velocity $\vec{v} = (3.00 \cdot 10^4 \text{ m/s})\hat{i}$. What are the magnitude and direction of the particle's acceleration produced by a uniform magnetic field $\vec{B} = (1.63 \text{ T})\hat{i} + (0.98 \text{ T})\hat{j}$?

Problem 12

The magnetic field \vec{B} in a certain region is 0.128 T , and its direction is that of the $+z$ -axis in figure. (a) What is the magnetic flux across the surface $abcd$? (b) What is the magnetic flux across the surface $befc$? (c) What is the magnetic flux across the surface $aefd$? (d) What is the net flux through all five surfaces that enclose the shaded volume?

Problem 15

An electron at point A in figure has a speed v_0 of $1.41 \cdot 10^6 \text{ m/s}$. Find (a) the magnitude and direction of the magnetic field that will cause the electron to follow the semi-circular path from A to B, and (b) the time required for the electron to move from A to B.

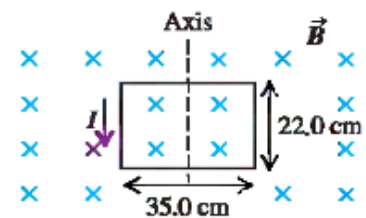


Problem 27

A proton ($q = 1.6 \cdot 10^{-19} \text{ C}$, $m = 1.67 \cdot 10^{-27} \text{ kg}$) moves in a uniform magnetic field $\vec{B} = (0.5 \text{ T})\hat{i}$. At $t = 0$ the proton has velocity components $v_x = 1.50 \cdot 10^5 \text{ m/s}$, $v_y = 0$. (a) What are the magnitude and direction of the magnetic force acting on the proton? In addition to the magnetic field there is a uniform electric field in the $+x$ -direction, $\vec{E} = (2.00 \cdot 10^4 \text{ V/m})\hat{i}$. (b) Will the proton have a component of acceleration in the direction of the electric field? (c) Describe the path of the proton. Does the electric field affect the radius of the helix? Explain. (d) At $t = T/2$, where T is the period of the circular motion of the proton, what is the x -component of the displacement of the proton from its position at $t = 0$?

Problem 44

A rectangular coil of wire, 22.0 cm by 35.0 cm and carrying a current of 1.40 A , is oriented with the plane of its loop perpendicular to a uniform 1.5 T magnetic field as shown figure. (a) Calculate the net force and torque that the magnetic field exerts on the coil. (b) The coil is rotated through a 30.0° angle about the axis shown, with the left side coming out of the plane of the figure and the right side going into the plane. Calculate the net force and torque that the magnetic field now exerts on the coil. (Hint: In order to help visualize this three-dimensional problem. make a careful drawing of the coil as viewed along the rotation axis.)



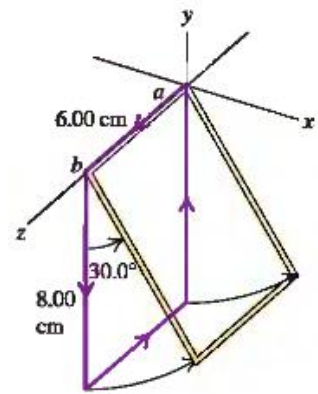
Problem 69

Two positive ions having the same charge q but different masses m_1 and m_2 are accelerated horizontally from rest through a potential difference V . They then enter a region where there is a uniform magnetic field \vec{B} normal to the plane of the trajectory. (a) Show that if the beam entered

the magnetic field along the x-axis, the value of the y-coordinate for each ion at any time t is approximately; $y = Bx^2 \left(\frac{q}{8mv} \right)^{1/2}$

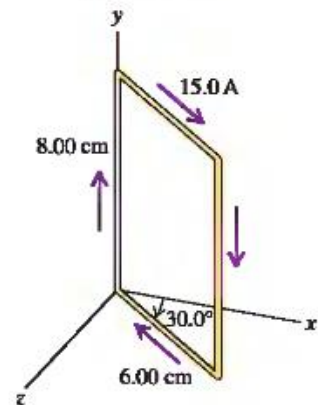
Problem 75

The rectangular loop of wire shown in figure has a mass of 0.15 g per centimeter of length and is pivoted about side ab on a frictionless axis. The current in the wire is 8.2 A in the direction shown. Find the magnitude and direction of the magnetic field parallel to the y-axis that will cause the loop to swing up until its plane makes an angle of 30.0° with the yz-plane.



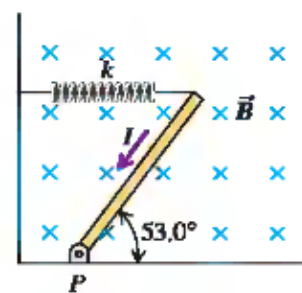
Problem 76

The rectangular loop shown in figure is pivoted about the y-axis and carries a current of 15.0 A in the direction indicated. (a) If the loop is in a uniform magnetic field with magnitude 0.48 T in the +x-direction. find the magnitude and direction of the torque required to hold the loop in the position shown. (b) Repeat part (a) for the case in which the field is in the -z-direction. (c) For each of the above magnetic fields. what torque would be required if the loop were pivoted about an axis through its center, parallel to the y-axis?



Problem 77

A thin, uniform rod with negligible mass and length 0.200 m is attached to the floor by a frictionless hinge at point P. A horizontal spring with force constant $k = 4.80 \text{ N/m}$ connects the other end of the rod to a vertical wall. The rod is in a uniform magnetic field $B = 0.34 \text{ T}$ directed into the plane of the figure. There is current $I = 6.5 \text{ A}$ in the rod, in the direction shown. (a) Calculate the torque due to the magnetic force on the rod, for an axis at P. Is it correct to take the total magnetic force to act at the center of gravity of the rod when calculating the torque? Explain. (b) When the rod is in equilibrium and makes an angle of 53.0° with the floor, is the spring stretched or compressed? (c) How much energy is stored in the spring when the rod is in equilibrium?



Problem 88

A circular ring with area 4.45 cm^2 is carrying a current of 12.5 A. The ring is free to rotate about a diameter. The ring, initially at rest, is immersed in a region of uniform magnetic field given by $\vec{B} = (1.15 \cdot 10^{-2} \text{ T}) + (12\hat{i} + 3\hat{j} - 4\hat{k})$. The ring is positioned initially such that its magnetic moment is given by $\vec{\mu}_i = \mu(-0.80\hat{i} + 0.62\hat{j})$, where μ is the (positive) magnitude of the magnetic moment. The ring is released and turns through an angle of 90.0°. at which point its magnetic moment is given by $\vec{\mu}_f = \mu\hat{k}$. (a) Determine the decrease in potential energy. (b) If the moment of inertia of the ring about a diameter is $8.5 \cdot 10^{-7} \text{ kg/m}^2$ determine the angular speed of the ring as it passes through the second position.

Problem 91

A Cycloidal Path: A particle with mass m and positive charge q starts from rest at the origin shown in figure. There is a uniform electric field \vec{E} in the $+y$ -direction and a uniform magnetic field \vec{B} directed out of the page. It is shown in more advanced books that the path is a cycloid whose radius of curvature at the top points is twice the y -coordinate at that level. (a) Explain why the path has this general shape and why it is repetitive. (b) Prove that the speed at any point is equal to

$$v = \sqrt{2qyE/m}.$$

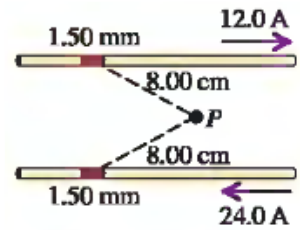
(Hint: Use energy conservation.) (c) Applying Newton's second law at the top point and taking as given that the radius of curvature here equals $2y$, prove that the speed at this point is $2E/B$.

Chapter 28

Problem 12, 19, 36, 37, 56, 59, 60, 76, 85, 87

Problem 12

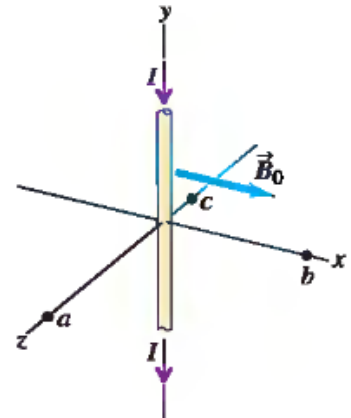
Two parallel wires are 5.00 cm apart and carry currents in opposite directions, as shown in figure. Find the magnitude and direction of the magnetic field at point P due to two 1.50-mm segments of wire that are opposite each other and each 8.00 cm from P. 8.00 cm from P.



Problem 19

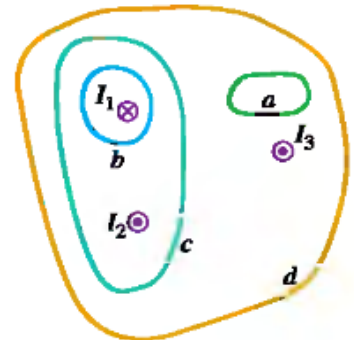
A long, straight wire lies along the y-axis and carries a current $I = 8.00$ A in the $-y$ -direction (see figure). In addition to the magnetic field due to the current in the wire, a uniform magnetic field \vec{B}_0 with magnitude $1.5 \cdot 10^{-6} T$ is in the $+x$ -direction. What is the total field (magnitude and direction) at the following points in the xz -plane:

- (a) $x = 0, z = 1.00 m$;
- (b) $x = 1.00 m, z = 0$;
- (c) $x = 0, z = 0.25 m$?



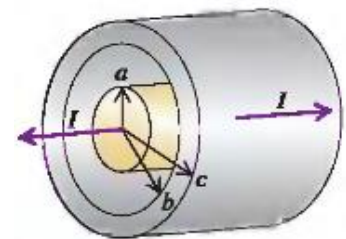
Problem 36

Figure shows, in cross section, several conductors that carry currents through the plane of the figure. The currents have the magnitudes $I_1 = 4.0 A, I_2 = 6.0 A,$ and $I_3 = 2.0 A,$ and the directions shown. Four paths, labeled a through d, are shown. What is the line integral $\oint \vec{B} \cdot d\vec{l}$ for each path? Each integral involves going around the path in the counterclockwise direction. Explain your answers.



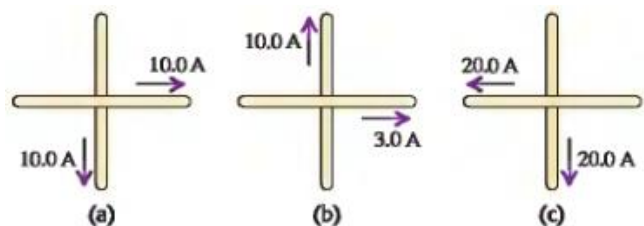
Problem 37

A solid conductor with radius a is supported by insulating disks on the axis of a conducting tube with inner radius b and outer radius c . The central conductor and tube carry equal currents I in opposite directions. The currents are distributed uniformly over the cross sections of each conductor. Derive an expression for the magnitude of the magnetic field (a) at points outside the central, solid conductor but inside the tube ($a < r < b$) and (b) at points outside the tube ($r > c$).



Problem 56

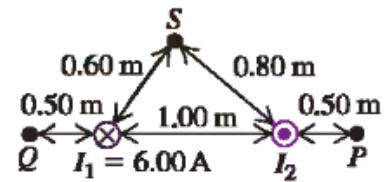
Two very long, straight wires carry currents as shown in figure. For each case, find all locations where the net magnetic field is zero.



Problem 59

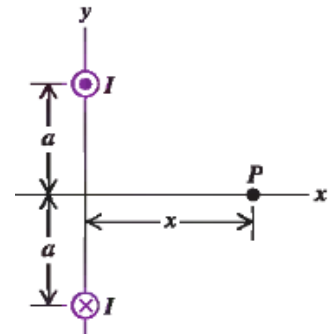
Two long, straight, parallel wires are 1.00 m apart. The wire on the left carries a current I_1 of 6.00 A into the plane of the paper. (a) What must

the magnitude and direction of the current I_2 be for the net field at point P to be zero? (b) Then what are the magnitude and direction of the net field at Q? (c) Then what is the magnitude of the net field at S?



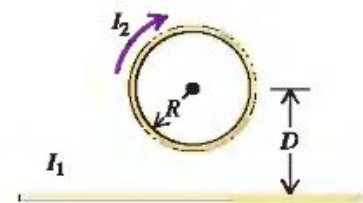
Problem 60

Figure shows an end view of two long, parallel wires perpendicular to the xy -plane, each carrying a current I but in opposite directions. (a) Copy the diagram, and draw vectors to show the \vec{B} field of each wire and the net \vec{B} field at point P. (b) Derive the expression for the magnitude of \vec{B} at any point on the x -axis in terms of the x -coordinate of the point. What is the direction of \vec{B} ? (c) Graph the magnitude of \vec{B} at points on the x -axis. (d) At what value of x is the magnitude of \vec{B} a maximum? (e) What is the magnitude of \vec{B} when $x \gg a$?



Problem 76

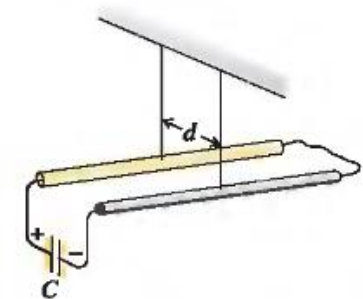
A circular loop has radius R and carries current I_2 in a clockwise direction. The center of the loop is a distance D above a long, straight wire. What are the magnitude and direction of the current I_1 in the wire if the magnetic field at the center of the loop is zero?



Problem 85

Two long, straight conducting wires with linear mass density λ are suspended from cords so that they are each horizontal, parallel to each other, and a distance d apart. The back ends of the wires are connected to each other by a slack, low-resistance connecting wire. A charged capacitor (capacitance C) is now added to the system; the positive plate of the capacitor (initial charge $+Q_0$) is connected to the front end of one of the wires, and the negative plate of the capacitor (initial charge $-Q_0$) is connected to the front end of the other wire (see figure). Both of these connections are also made by slack, low-resistance wires. When the connection is made, the wires are pushed aside by the repulsive force between the wires, and each wire has an initial horizontal velocity of magnitude v_0 . Assume that the time constant for the capacitor to discharge is negligible compared to the time it takes for any appreciable displacement in the position of the wires to occur. (a) Show that the initial speed v_0 of either wire is given by;

$$v_0 = \frac{\mu_0 Q_0^2}{4\pi\lambda R C d}$$



Problem 87

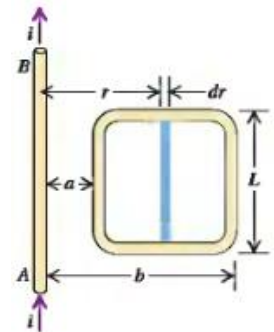
A Charged Dielectric Disk. A thin disk of dielectric material with radius a has a total charge $+Q_0$ distributed uniformly over its surface. It rotates n times per second about an axis perpendicular to the surface of the disk and passing through its center. Find the magnetic field at the center of the disk. (Hint: Divide the disk into concentric rings of infinitesimal width.)

Chapter 29

Problem 7, 25, 27, 28, 36, 45, 60, 61, 65, 77

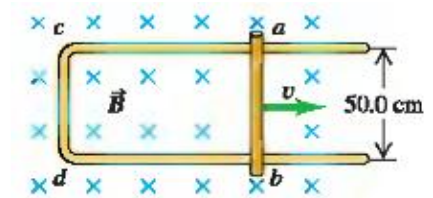
Problem 7

The current in the long, straight wire AB shown in figure is upward and is increasing steadily at a rate $\frac{di}{dt}$. (a) At an instant when the current is i , what are the magnitude and direction of the field \vec{B} at a distance r to the right of the wire? (b) What is the flux $d\phi_B$ through the narrow, shaded strip? (c) What is the total flux through the loop? (d) What is the induced emf in the loop? (e) Evaluate the numerical value of the induced emf if $a = 12.0 \text{ cm}$, $a = 36.0 \text{ cm}$, $L = 24.0 \text{ cm}$, and $di/dt = 9.60 \text{ A/s}$.



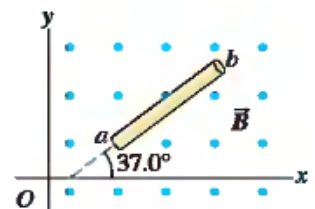
Problem 25

The conducting rod ab shown in figure makes contact with metal rails ca and db . The apparatus is in a uniform magnetic field of 0.800 T , perpendicular to the plane of the figure (a) Find the magnitude of the emf induced in the rod when it is moving toward the right with a speed 7.50 m/s . (b) In what direction does the current flow in the rod? (c) If the resistance of the circuit $abcd$ is 1.5Ω (assumed to be constant), find the force (magnitude and direction) required to keep the rod moving to the right with a constant speed of 7.50 m/s . You can ignore friction. (d) Compare the rate at which mechanical work is done by the force (Fv) with the rate at which thermal energy is developed in the circuit (I^2R).



Problem 27

A 1.41 m bar moves through a uniform, 1.20 T magnetic field with a speed of 2.50 m/s (see figure). In each case, find the emf induced between the ends of this bar and identify which, if any, end (a or b) is at the higher potential. The bar moves in the direction of (a) the $+x$ -axis; (b) the $-y$ -axis; (c) the $+z$ -axis. (d) How should this bar move so that the emf across its ends has the greatest possible value with b at a higher potential than a , and what is this maximum emf?

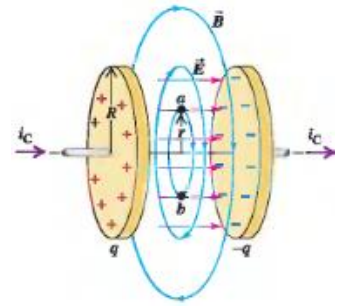


Problem 28

A long, thin solenoid has 900 turns per meter and radius 250 cm . The current in the solenoid is increasing at a uniform rate of 60.0 A/s . What is the magnitude of the induced electric field at a point near the center of the solenoid and (a) 0.500 cm from the axis of the solenoid; (b) 1.00 cm from the axis of the solenoid?

Problem 36

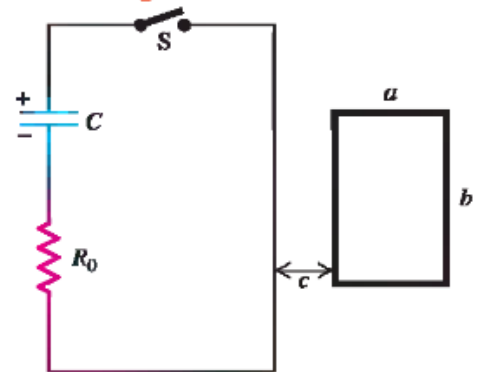
A parallel-plate, air-filled capacitor is being charged as in figure. The circular plates have radius 4.00 cm, and at a particular instant the conduction current in the wires is 0.280 A. (a) What is the displacement current density J_D in the air space between the plates? (b) What is the rate at which the electric field between the plates is changing? (c) What is the induced magnetic field between the plates at a distance of 2.00 cm from the axis? (d) At 1.00 cm from the axis?



Problem 45

In the circuit shown in Fig. 29.41 the capacitor has capacitance $C = 20 \mu\text{F}$ and is initially charged to 100 V with the polarity shown. The resistor R_0 has resistance 10Ω . At time $t = 0$ the switch is closed. The small circuit is not connected in any way to the large one. The wire of the small circuit has a resistance of $1.0 \Omega / \text{m}$ and contains 25 loops. The large circuit is a rectangle 2.0 m by 4.0 m, while the small one has dimensions $a = 10.0 \text{ cm}$ and $b = 20.0 \text{ cm}$. The distance c is 5.0 cm. (The figure is not drawn to scale.) Both circuits are held stationary. Assume that only the wire nearest the small circuit produces an appreciable magnetic field through it. (a) Find the current in the large circuit 200 μs after S is closed. (b) Find the current in the small circuit 200 μs after S is closed. (Hint: See Problem 29.7.) (c) Find the direction of the current in the small circuit. (d) Justify why we can ignore the magnetic field from all the wires of the large circuit except for the wire closest to the small circuit.

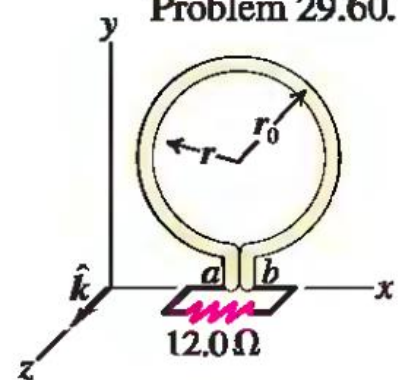
Figure 29.41 Problem 29.45.



Problem 60

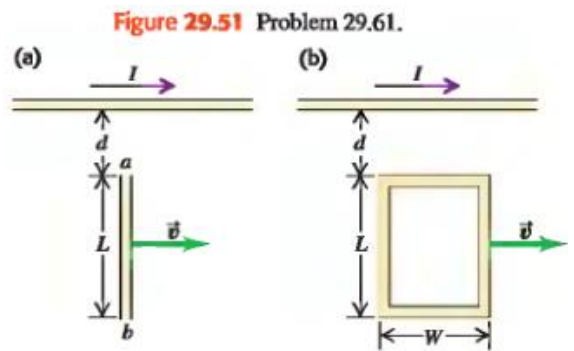
A circular conducting ring with radius $r_0 = 0.0420 \text{ m}$ lies in the xy -plane in a region of uniform magnetic field $\vec{B}_0 = B_0[1 - 3(t/t_0)^2 + 2(t/t_0)^3]\hat{k}$. In this expression, $t_0 = 0.0100 \text{ s}$ and is constant, t is time, \hat{k} is the unit vector in the $+z$ -direction, and $B_0 = 0.0800 \text{ T}$ and is constant. At points a and b (Fig. 29.50) there is a small gap in the ring with wires leading to an external circuit of resistance $R = 12.0 \Omega$. There is no magnetic field at the location of the external circuit. (a) Derive an expression, as a function of time, for the total magnetic flux ϕ_B through the ring. (b) Determine the emf induced in the ring at time $t = 5.0 \times 10^{-3} \text{ s}$. What is the polarity of the emf? (c) Because of the internal resistance of the ring, the current through R at the time given in part (b) is only 3.00 mA. Determine the internal resistance of the ring. (d) Determine the emf in the ring at a time $t = 1.21 \times 10^{-2} \text{ s}$. What is the polarity of the emf? (e) Determine the time at which the current through R reverses its direction.

Figure 29.50 Problem 29.60.



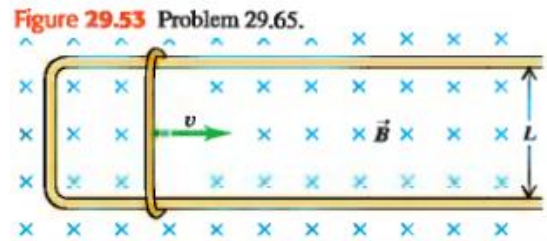
Problem 61

The long, straight wire shown in Fig. 29.51a carries constant current I . A metal bar with length L is moving at constant velocity v , as shown in the figure. Point a is a distance d from the wire. (a) Calculate the emf induced in the bar. (b) Which point, a or b , is at higher potential? (c) If the bar is replaced by a rectangular wire loop of resistance R (Fig. 29.51b), what is the magnitude of the current induced in the loop?



Problem 65

A rectangular loop with width L and a slide wire with mass m are as shown in Fig. 29.53. A uniform magnetic field B is directed perpendicular to the plane of the loop into the plane of the figure. The slide wire is given an initial speed of V_0 and then released. There is no friction between the slide wire and the loop, and the resistance of the loop is negligible in comparison to the resistance R of the slide wire. (a) Obtain an expression for F , the magnitude of the force exerted on the wire while it is moving at speed V . (b) Show that the distance x that the wire moves before coming to rest is $x = mV_0R/(a^2B^2)$.



Problem 77

A metal bar with length L , mass m , and resistance R is placed on frictionless metal rails that are inclined at an angle ϕ above the horizontal. The rails have negligible resistance. A uniform magnetic field of magnitude B is directed downward as shown in Fig. 29.57. The bar is released from rest and slides down the rails. (a) Is the direction of the current induced in the bar from a to b or from b to a ? (b) What is the terminal speed of the bar? (c) What is the induced current in the bar when the terminal speed has been reached? (d) After the terminal speed has been reached, at what rate is electrical energy being converted to thermal energy in the resistance of the bar? (e) After the terminal speed has been reached, at what rate is work being done on the bar by gravity? Compare your answer to that in part (d).

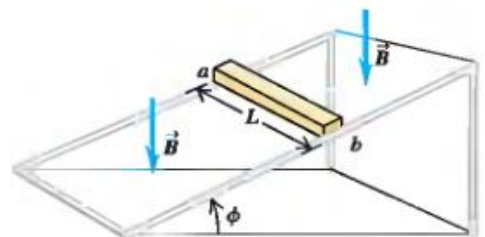


Figure 29.57 Challenge Problem 29.77.

Chapter 30

Problem 3, 11, 23, 43, 48, 49, 62, 63, 73

Problem 3

From Eq. (30.5) $1 \text{ H} = 1 \text{ Wb/A}$, and from Eq. (30.4) $1 \text{ H} = 1 \Omega \cdot \text{s}$. Show that these two definitions are equivalent.

Problem 11

Inductance of a Solenoid. A long, straight solenoid has N turns, uniform cross-sectional area A , and length l . Show that the inductance of this solenoid is given by the equation $L = \mu_0 AN^2/l$. Assume that the magnetic field is uniform inside the solenoid and zero outside. (Your answer is approximate because B is actually smaller at the ends than at the center. For this reason, your answer is actually an upper limit on the inductance.)

Problem 23

Show that L/R has units of time.

Problem 43

One solenoid is centered inside another. The outer one has a length of 50.0 cm and contains 6750 coils, while the coaxial inner solenoid is 3.0 cm long and 0.120 cm in diameter and contains 15 coils. The current in the outer solenoid is changing at 37.5 A/s. (a) what is the mutual inductance of these solenoids? (b) Find the emf induced in the inner solenoid.

Problem 48

A Coaxial Cable. A small solid conductor with radius a is supported by insulating, nonmagnetic disks on the axis of a thin walled tube with inner radius b . The inner and outer conductors carry equal currents i in opposite directions. (a) Use Ampere's law to find the magnetic field at any point in the volume between the conductors. (b) Write the expression for the flux $\frac{d\phi_b}{dt}$ through a narrow strip of length l parallel to the axis, of width dr , at a distance r from the axis of the cable and lying in a plane containing the axis. (c) Integrate your expression from part (b) over the volume between the two conductors to find the total flux produced by a current i in the central conductor. (d) Show that the inductance of a length l of the cable is

$$L = l \frac{\mu_0}{2\pi} \ln\left(\frac{b}{a}\right)$$

(e) Use Eq. (30.9) to calculate the energy stored in the magnetic field for a length l of the cable.

Problem 49

Consider the coaxial cable of Problem 30.48. The conductors carry equal currents i in opposite directions. (a) Use Ampere's law to find the magnetic field at any point in the volume between the conductors. (b) Use the energy density for a magnetic field, Eq. (30.10), to calculate the energy stored in a thin, cylindrical shell between the two conductors. Let the cylindrical shell have inner radius r , outer radius $r + dr$, and length l . (c) Integrate your result in part (b) over the volume between the two conductors to find the total energy stored in the magnetic field for a length l of the cable. (d) Use your result in part (c) and Eq. (30.9) to calculate the inductance L of a length l of the cable. Compare your result to L calculated in part (d) of Problem 30.48.

Figure 30.22 Problem 30.62.

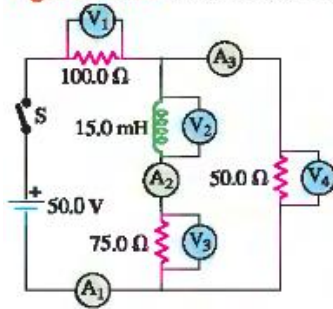
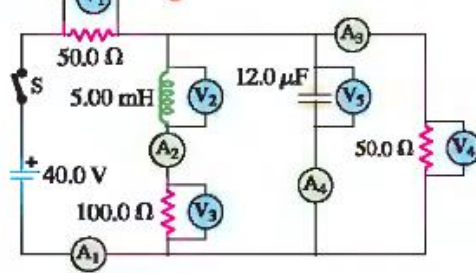


Figure 30.23 Problem 30.63.



Problem 62

In the circuit shown in Figure 30.22 find the reading in each ammeter and voltmeter (a) just after switch S is closed and (b) after S has been closed a very long time.

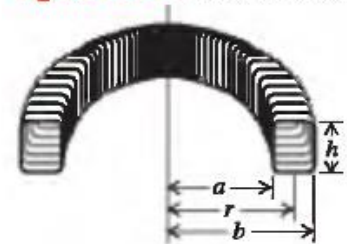
Problem 63

In the circuit shown in Fig. 30.23, switch S is closed at time $t = 0$ with no charge initially on the capacitor. (a) Find the reading of each ammeter and each voltmeter just after S is closed. (b) Find the reading of each meter after a long time has elapsed. (c) Find the maximum charge on the capacitor. (d) Draw a qualitative graph of the reading of voltmeter V_2 as a function of time.

Problem 73

We have ignored the variation of the magnetic field across the cross section of a toroidal solenoid. Let's now examine the validity of that approximation. A certain toroidal solenoid has a rectangular cross section (Fig. 30.31). It has N uniformly spaced turns, with air inside. The magnetic field at a point inside the toroid is given by the equation derived in Example 28.11 (Section 28.7). Do not assume the field is uniform over the cross section. (a) Show that the magnetic flux through a cross section of the toroid is

Figure 30.31 Problem 30.73.



$$\phi_B = \frac{\mu_0 N i h}{2\pi} \ln\left(\frac{b}{a}\right)$$

(b) Show that the inductance of the toroidal solenoid is given by

$$L = \frac{\mu_0 N^2 h}{2\pi} \ln\left(\frac{b}{a}\right)$$

(c) The fraction b/a may be written as

$$\frac{b}{a} = \frac{a + b - a}{a} = 1 + \frac{b - a}{a}$$

Use the power series expansion $\ln(1 + z) = z + \frac{z^2}{2} + \dots$

to show that when $b - a$ is much less than a , the inductance is approximately equal to

$$L = \frac{\mu_0 N^2 h}{2\pi a} (b - a)$$

Chapter 32

Problem 5, 7, 8, 9, 13, 16, 40, 46, 47, 55

Problem 5

A sinusoidal electromagnetic wave having a magnetic field of amplitude $1.25 \mu\text{ T}$ and a wavelength of 432 nm is traveling in the $+x$ direction through empty space. (a) What is the frequency of this wave? (b) What is the amplitude of the associated electric field? (c) Write the equations for the electric and magnetic fields as functions of x and t in the form of Eqs. (32.17).

Problem 7

A sinusoidal electromagnetic wave of frequency $6 \times 10^{14} \text{ Hz}$ travels in vacuum in the $+z$ direction. The \vec{B} field is parallel to the y axis and has amplitude $5.8 \times 10^{-4} \text{ T}$. Write the vector equations for $\vec{E}(z, t)$ and $\vec{B}(z, t)$.

Problem 9

An electromagnetic wave has an electric field given

$$\vec{E}(y, t) = -\left(3.1 \times 10^5 \frac{\text{V}}{\text{m}}\right) \hat{k} \cdot \sin[ky - (12.56 \times 10^{12} \text{ rad/s})t]$$

(a) In which direction is the wave traveling? (b) What is the wavelength of the wave? (c) Write the vector equation for $\vec{B}(y, t)$.

Problem 13

An electromagnetic wave with frequency $5.7 \times 10^{14} \text{ Hz}$ propagates with a speed of $2.17 \times 10^8 \text{ m/s}$ in a certain piece of glass. Find (a) the wavelength of the wave in the glass; (b) the wavelength of a wave of the same frequency propagating in air; (c) the index of refraction n of the glass for an electromagnetic wave with this frequency; (d) the dielectric constant for glass at this frequency, assuming that the relative permeability is unity.

Problem 16

Consider each of the following electric and magnetic-field orientations. In each case, what is the direction of propagation of the wave?

(a) $\vec{E} = E\hat{i}, \vec{B} = -B\hat{j}$

(b) $\vec{E} = E\hat{j}, \vec{B} = B\hat{i}$

(c) $\vec{E} = -E\hat{k}, \vec{B} = -B\hat{i}$

(d) $\vec{E} = E\hat{i}, \vec{B} = -B\hat{k}$

Problem 40

A plane sinusoidal electromagnetic wave in air has a wavelength of 3.84 cm and an E-field amplitude of 1.35 V/m . (a) What is the frequency? (b) What is the B-field amplitude? (c) What is the intensity? (d) What average force does this radiation exert on a totally absorbing surface with area 0.240 m^2 perpendicular to the direction of propagation?

Problem 46

The plane of a flat surface is perpendicular to the propagation direction of an electromagnetic wave of intensity I . The surface absorbs a fraction w of the incident intensity, where $0 \leq w \leq 1$, and

reflects the rest. (a) Show that the radiation pressure on the surface equals $(2 - w)I/c$. (b) Show that this expression gives the correct results for a surface that is (i) totally absorbing and (ii) totally reflective. (c) For an incident intensity of 1.40 kW/m^2 , what is the radiation pressure for 90% absorption? For 90% reflection?

Problem 47

A cylindrical conductor with a circular cross section has a radius a and a resistivity ρ and carries a constant current I . (a) What are the magnitude and direction of the electric-field vector \vec{E} at a point just inside the wire at a distance a from the axis? (b) What are the magnitude and direction of the magnetic-field vector \vec{B} at the same point? (c) What are the magnitude and direction of the Poynting vector \vec{S} at the same point? (The direction of \vec{S} is the direction in which electromagnetic energy flows into or out of the conductor.) (d) Use the result in part (c) to find the rate of flow of energy into the volume occupied by a length l of the conductor. (Hint: Integrate \vec{S} over the surface of this volume.) Compare your result to the rate of generation of thermal energy in the same volume. Discuss why the energy dissipated in a current-carrying conductor, due to its resistance, can be thought of as entering through the cylindrical sides of the conductor.

Problem 55

Interplanetary space contains many small particles referred to as interplanetary dust. Radiation pressure from the sun sets a lower limit on the size of such dust particles. To see the origin of this limit, consider a spherical dust particle of radius R and mass density ρ . (a) Write an expression for the gravitational force exerted on this particle by the sun (mass M) when the particle is a distance r from the sun. (b) Let L represent the luminosity of the sun, equal to the rate at which it emits energy in electromagnetic radiation. Find the force exerted on the (totally absorbing) particle due to solar radiation pressure, remembering that the intensity of the sun's radiation also depends on the distance r . The relevant area is the cross-sectional area of the particle, not the total surface area of the particle. As part of your answer, explain why this is so. (c) The mass density of a typical interplanetary dust particle is about 3000 kg/m^3 . Find the particle radius R such that the gravitational and radiation forces acting on the particle are equal in magnitude. The luminosity of the sun is $3.9 \times 10^{26} \text{ W}$. Does your answer depend on the distance of the particle from the sun? Why or why not? (d) Explain why dust particles with a radius less than that found in part (c) are unlikely to be found in the solar system. [Hint: Construct the ratio of the two force expressions found in parts (a) and (b).]