PHYSICS 200

Problems

Foundations of Physics II

PHYS 200
Sections 01A & 02A
MTRF 1:30 & 1:00
PEngel 167 & 173

Text:
University Physics
Young & Freedman

Spring 2021
Blocks C & D
Tom Kirkman

==> c1-20.txt <==
21.3 If a proton and an electron are released when they are 2.0×10^{-10} m apart (a typical atomic distance), find the initial acceleration of each particle.

Proton mass = 1.6726×10^{-27} kg
Electron mass = 9.1094×10^{-31} kg
Charge on a proton: $e = 1.6022 \times 10^{-19}$ C

21.6 Two small spheres spaced 20.0 cm apart have equal charge. How many excess electrons must be present on each sphere if the magnitude of the force of repulsion between them is 3.33×10^{-21} N?

21.17 Two point charges are located on the y-axis as follows: charge $q_1=-1.50$ nC at $y=-0.600$ m, and charge $q_2=+3.20$ nC at the origin ($y=0$). What is the total force (magnitude and direction) exerted by these two charges on a third charge $q_3=+5.00$ nC located at $y=-0.400$ m?

==> c2-20.txt <==
Example 21.4 Two equal positive charges $q_1=q_2=2.0\ \mu C$ are located at $x=0$, $y=0.30$ m and $x=0$, $y=-0.30$ m, respectively. What are the magnitude and direction of the total electric force that q_1 and q_2 exert on a third charge $Q=4.0\ \mu C$ at $x=0.40$ m, $y=0$?

21.43 In a rectangular coordinate system a positive point charge $q=6.00\times10^{-9}$ C is placed at the point $x=+0.150$ m, $y=0$, and an identical point charge is placed at $x=-0.150$ m, $y=0$. Find the x- and y-components, the magnitude, and the direction of the electric field at the following points: (a) the origin; (b) $x=0.300$ m, $y=0$; (c) $x=0.150$ m, $y=-0.400$ m; (d) $x=0$, $y=0.200$ m.

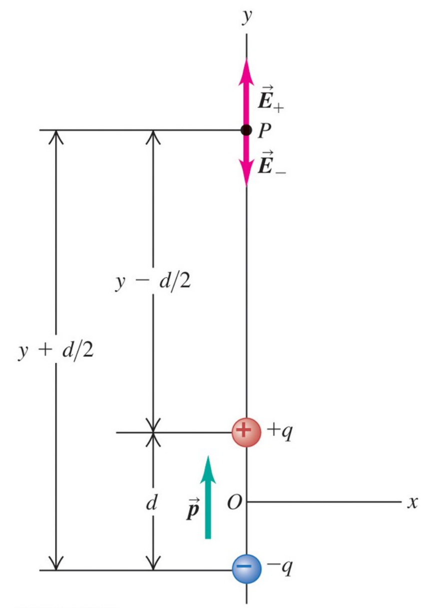
21.44 A point charge $q_1=-4.00$ nC is at the point $x=0.600$ m, $y=0.800$ m, and a second point charge $q_2=+6.00$ nC is at the point $x=0.600$ m, $y=0$. Calculate the magnitude and direction of the net electric field at the origin due to these two point charges.

==> c3-20.txt <==
21.52 The ammonia molecule (NH_3) has a dipole moment of 5.0×10^{-30} C·m. Ammonia molecules in the gas phase are placed in a uniform electric field $\vec{E}$ with magnitude 1.6×10^6 N/C. (a) What is the change in electric potential energy when the dipole moment of a molecule changes its orientation with respect to $\vec{E}$ from parallel to perpendicular? (b) At what absolute temperature T is the average translational kinetic energy $3/2\ K_b T$ of a molecule equal to the change in potential energy calculated in part (a)? (Note: Above this temperature, thermal agitation prevents the dipoles from aligning with the electric field.)

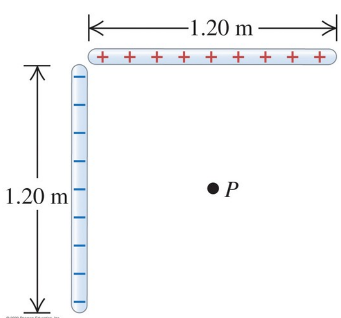
Boltzmann's constant: $K_b = 1.3806 \times 10^{-23}$ J/K

Example 21.14 Field of an electric dipole

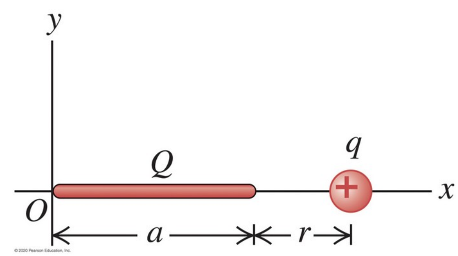
An electric dipole is centered at the origin, with $\vec{p}$ in the direction of the +y-axis (Fig. 21.33). Derive an approximate expression for the electric field at a point P on the y-axis for which y is much larger than d. To do this, use the binomial expansion $(1+x)^n \cong 1+nx+n(n-1)x^2/2+\cdots$ (valid for the case $|x|<1$).



21.85 Two 1.20 m non-conducting rods meet at a right angle. One rod carries +2.50 μC of charge distributed uniformly along its length, and the other carries −2.50 μC distributed uniformly along it (Fig. P21.85). (a) Find the magnitude and direction of the electric field these rods produce at point P, which is 60.0 cm from each rod. (b) If an electron is released at P, what are the magnitude and direction of the net force that these rods exert on it?

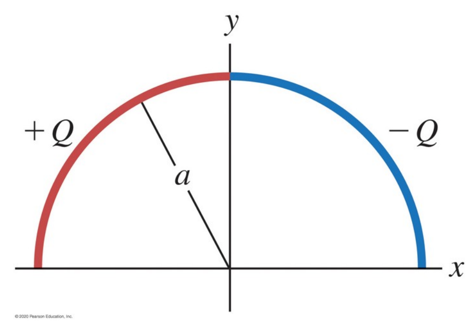


==> c4-20.txt <==
21.79 CALC Positive charge Q is distributed uniformly along the x-axis from x=0 to x=a. A positive point charge q is located on the positive x-axis at x=a+r, a distance r to the right of the end of Q (Fig. P21.79). (a) Calculate the x- and y-components of the electric field produced 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≫a, the magnitude of the force in part (b) is approximately Qq/4πϵ0 r^2. Explain why this result is obtained.



21.83 CALC Negative charge −Q is distributed uniformly around a quarter-circle of radius a that lies in the first quadrant, with the center of curvature at the origin. Find the x- and y-components of the net electric field at the origin.

21.84 CALC A semicircle of radius a is in the first and second quadrants, with the center of curvature at the origin. Positive charge +Q is distributed uniformly around the left half of the semicircle, and negative charge −Q is distributed uniformly around the right half of the semicircle (Fig. P21.84). What are the magnitude and direction of the net electric field at the origin produced by this distribution of charge?



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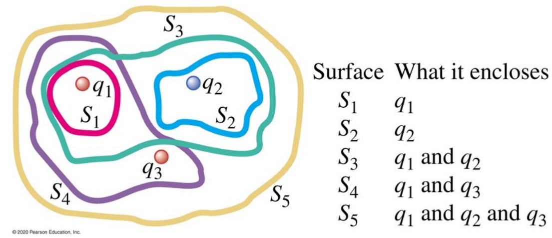
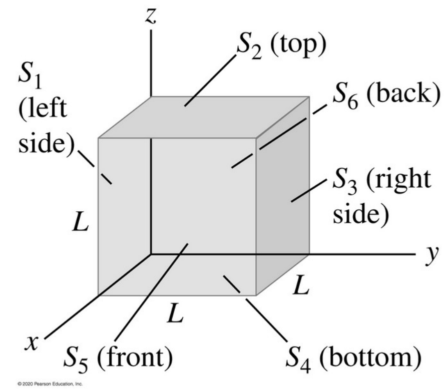


22.8 • The three small spheres shown in Fig. E22.8 carry charges q1=4.00 nC, q2=−7.80 nC, and q3=2.40 nC. Find the net electric flux through each of the following closed surfaces shown in cross section in the figure: (a) S1 ; (b) S2 ; (c) S3 ; (d) S4 ; (e) S5 . (f) Do your answers to parts (a)–(e) depend on how the charge is distributed over each small sphere? Why or why not?



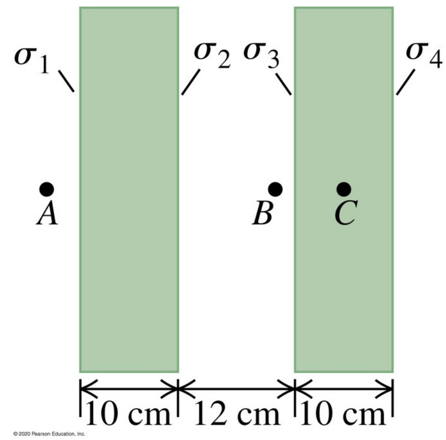
22.32 A cube has sides of length L=0.300 m. One corner is at the origin (Fig. E22.6). The nonuniform electric field is given by $\vec{E}$ =(−5.00 N/C·m)x i+(3.00 N/C·m)z k. (a) Find the electric flux through each of the six cube faces S1, S2, S3, S4, S5, and S6 . (b) Find the total electric charge inside the cube.

22.34 CALC In a region of space there is an electric field $\vec{E}$ that is in the z-direction and that has magnitude E=[964 N/(C·m)]x. Find the flux for this field through a square in the xy-plane at z=0 and with side length 0.350 m. One side of the square is along the +x-axis and another side is along the +y-axis.

==> c6-20.txt <==

22.17 A very long uniform line of charge has charge per unit length 4.80 μC/m and lies along the x-axis. A second long uniform line of charge has charge per unit length −2.40 μC/m and is parallel to the x-axis at $y=0.400$ m. What is the net electric field (magnitude and direction) at the following points on the y-axis: (a) $y=0.200$ m and (b) $y=0.600$ m?

22.28 Two very large, nonconducting plastic sheets, each 10.0 cm thick, carry uniform charge densities σ_1, σ_2, σ_3, and σ_4 on their surfaces (Fig. E22.28). These surface charge densities have the values $\sigma_1=-6.00$ μC/m^2, $\sigma_2=+5.00$ μC/m^2, $\sigma_3=+2.00$ μC/m^2, and $\sigma_4=+4.00$ μC/m^2. Use Gauss’s law to find the magnitude and direction of the electric field at the following points, far from the edges of these sheets: (a) point A, 5.00 cm from the left face of the left-hand sheet; (b) point B, 1.25 cm from the inner surface of the right-hand sheet; (c) point C, in the middle of the right-hand sheet.

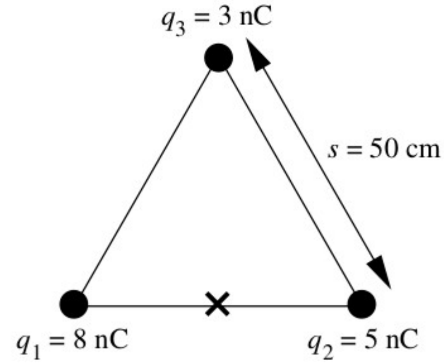


22.37 The Coaxial Cable. A long coaxial cable consists of an inner cylindrical conductor with radius a and an outer coaxial cylinder with inner radius b and outer radius c. The outer cylinder is mounted on insulating supports and has no net charge. The inner cylinder has a uniform positive charge per 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.

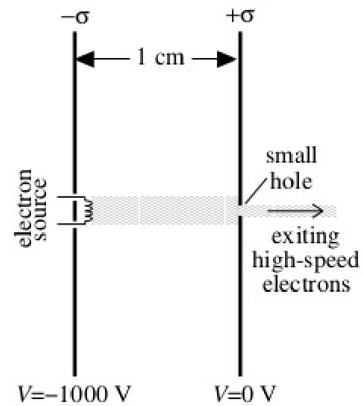
22.41 A solid conducting sphere with radius R that carries positive charge Q is concentric with a very thin insulating shell of radius 2R that also carries charge Q. The charge Q is distributed uniformly over the insulating shell. (a) Find the electric field (magnitude and direction) in each of the regions $0<r<R$, $R<r<2R$, and $r>2R$. (b) Graph the electric-field magnitude as a function of r.

==> c7-20.txt <==

11. As shown below three charges are arranged in an equilateral triangle with side 50 cm.
A. Find the electric field vector at the spot marked X (i.e., the midpoint of the horizontal segment).
B. Find the voltage at the spot marked X. (Assume as usual: V (∞) = 0.)

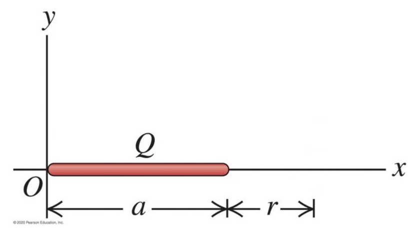


2. An electron 'gun' consists of two oppositely charged parallel plates separated by 1 cm. An electron source (a hot wire) is at the voltage of the negatively charged plate (i.e., V = −1000 V). The ejected electrons initially have zero velocity; they are accelerated as they approach the positively charged plate. The positively charge plate (which is grounded, i.e., V = 0 V) has a small hole through which some of the fast moving electrons can exit
A. How fast are the electrons moving when they exit the hole?
B. What is the direction and magnitude of the electric field between the plates?



23.27 A thin spherical shell with radius R1=3.00 cm is concentric with a larger thin spherical shell with radius R2=5.00 cm. Both shells are made of insulating material. The smaller shell has charge q1=+6.00 nC distributed uniformly over its surface, and the larger shell has charge q2=−9.00 nC distributed uniformly over its surface. Take the electric potential to be zero at an infinite distance from both shells. (a) What is the electric potential due to the two shells at the following distance from their common center: (i) r=0; (ii) r=4.00 cm; (iii) r=6.00 cm? (b) What is the magnitude of the potential difference between the surfaces of the two shells? Which shell is at higher potential: the inner shell or the outer shell?

==> c8-20.txt <==
21.79 CALC Positive charge Q is distributed uniformly along the x-axis from x=0 to x=a. (a) Calculate the electric potential produced by the charge distribution Q at points on the positive x-axis where x>a. (b) Calculate the x-component of the electric field produced by the charge distribution Q at points on the positive x-axis where x>a. (c) Show that for large $r \gg a$, the electric potential is approximately $Q/4\pi\epsilon_0 r$.



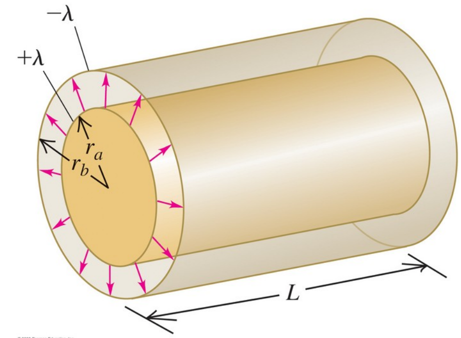
23.66 CALC A disk with radius R has uniform surface charge density σ. (a) By regarding the disk as a series of thin concentric rings, calculate the electric potential V at a point on the disk’s axis a distance x from the center of the disk. Assume that the potential is zero at infinity. (b) Calculate $-\partial V/\partial x$.

23.69 Charge Q=+4.00 μC is distributed uniformly over the volume of an insulating sphere that has radius R=5.00 cm. What is the potential difference between the center of the sphere and the surface of the sphere?

==> c11-20.txt <==

Example 24.4

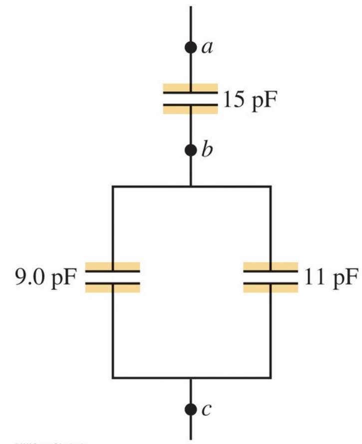
Two long, coaxial cylindrical conductors are separated by vacuum (Fig. 24.6). The inner cylinder has outer radius ra and linear charge density +λ. The outer cylinder has inner radius rb and linear charge density −λ. Find the capacitance per unit length for this capacitor.



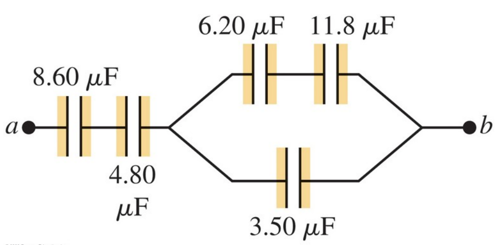
24.3 A parallel-plate air capacitor of capacitance 245 pF has a charge of magnitude 0.148 μC on each plate. The plates are 0.328 mm apart. (a) What is the potential difference between the plates? (b) What is the area of each plate? (c) What is the electric-field magnitude between the plates? (d) What is the surface charge density on each plate?

epsilon0 = 8.8542 × 10^-12 F/m

24.16 For the system of capacitors shown in Fig. E24.16, find the equivalent capacitance (a) between b and c, and (b) between a and c.



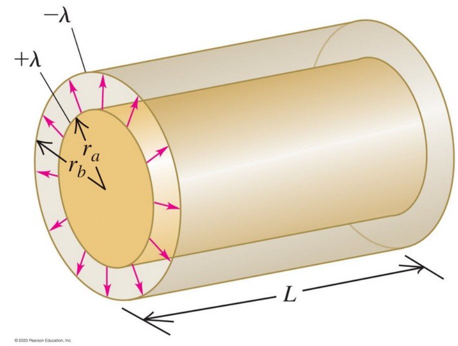
24.51 For the capacitor network shown in Fig. P24.51, the potential difference across ab is 12.0 V. Find (a) the total energy stored in this network and (b) the energy stored in the 4.80 μF capacitor.



==> c12-20.txt <==

24.11 A spherical capacitor contains a charge of 3.30 nC when connected to a potential difference of 220 V. If its plates are separated by vacuum and the inner radius of the outer shell is 4.00 cm, calculate: (a) the capacitance; (b) the radius of the inner sphere; (c) the electric field just outside the surface of the inner sphere.

24.62 CALC The inner cylinder of a long, cylindrical capacitor has radius ra and linear charge density $+\lambda$. It is surrounded by a coaxial cylindrical conducting shell with inner radius rb and linear charge density $-\lambda$ (see Fig. 24.6). (a) What is the energy density in the region between the conductors at a distance r from the axis? (b) Integrate the energy density calculated in part (a) over the volume between the conductors in a length L of the capacitor to obtain the total electric-field energy per unit length. (c) Use Eq. (24.9) and the capacitance per unit length calculated in Example 24.4 (Section 24.1) to calculate U/L. Does your result agree with that obtained in part (b)?



==> c13-20.txt <==

24.33 Two parallel plates have equal and opposite charges. When the space between the plates is evacuated, the electric field is $E=3.20\times10^5$ V/m. When the space is filled with dielectric, the electric field is $E=2.50\times10^5$ V/m. (a) What is the charge density on each surface of the dielectric? (b) What is the dielectric constant?

24.39 A constant potential difference of 12 V is maintained between the terminals of a 0.25 μF, parallel-plate, air capacitor. (a) A sheet of Mylar is inserted between the plates of the capacitor, completely filling the space between the plates. When this is done, how much additional charge flows onto the positive plate of the capacitor (see Table 24.1)? (b) What is the total induced charge on either face of the Mylar sheet? (c) What effect does the Mylar sheet have on the electric field between the plates? Explain how you can reconcile this with the increase in charge on the plates, which acts to increase the electric field.
($K=3.1$)

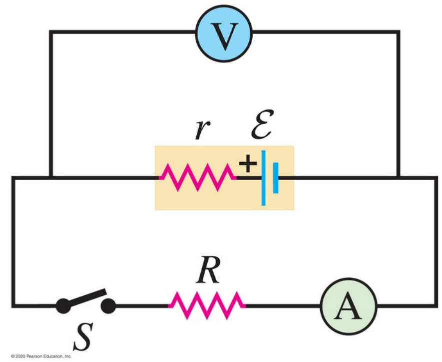
24.40 Polystyrene has dielectric constant 2.6 and dielectric strength 2.0×10^7 V/m. A piece of polystyrene is used as a dielectric in a parallel-plate capacitor, filling the volume between the plates. (a) When the electric field between the plates is 80% of the dielectric strength, what is the energy density of the stored energy? (b) When the capacitor is connected to a battery with voltage 500.0 V, the electric field between the plates is 80% of the dielectric strength. What is the area of each plate if the capacitor stores 0.200 mJ of energy under these conditions?

==> c14-20.txt <==
ρ Cu=1.72e-8 $\Omega\cdot$m
ρ Ag=1.47e-8
ρ Al=2.75e-8

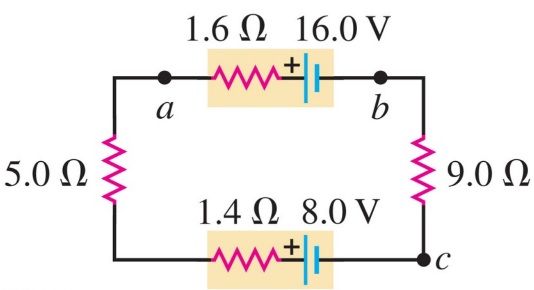
25.12 (a) At room temperature, what is the strength of the electric field in a 12 gauge copper wire (diameter 2.05 mm) that is needed to cause a 4.50 A current to flow? (b) What field would be needed if the wire were made of silver instead?

25.20 What diameter must a copper wire have if its resistance is to be the same as that of an equal length of aluminum wire with diameter 2.14 mm?

25.29 When switch S in Fig. E25.29 is open, the voltmeter V reads 3.08 V. When the switch is closed, the voltmeter reading drops to 2.97 V, and the ammeter A reads 1.65 A. Find the emf, the internal resistance of the battery, and the circuit resistance R. Assume that the two meters are ideal, so they don’t affect the circuit.



25.30 The circuit shown in Fig. E25.30 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 Vab of the 16.0 V battery; (c) the potential difference Vac of point a with respect to point c.



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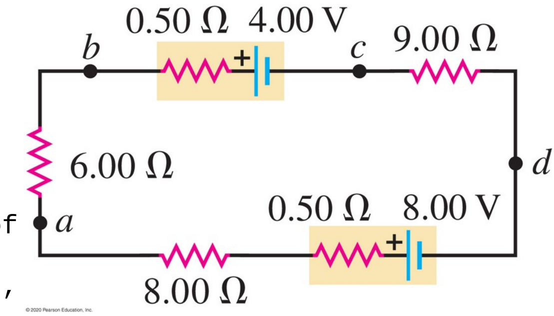
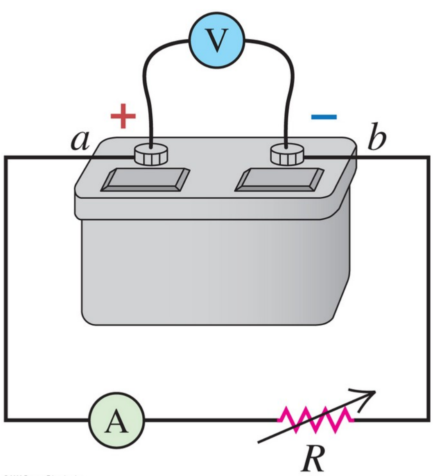


25.62 (a) What is the potential difference Vad in the circuit of Fig. P25.62? (b) What is the terminal voltage of the 4.00 V battery? (c) A battery with emf 10.30 V and internal resistance 0.50 Ω is inserted in the circuit at d, with its negative terminal connected to the negative terminal of the 8.00 V battery. What is the difference of potential Vbc between the terminals of the 4.00 V battery now?

25.65 A typical cost for electrical power is $0.120 per kilowatt-hour. (a) Some people leave their porch light on all the time. What is the yearly cost to keep a 75 W bulb burning day and night? (b) Suppose your refrigerator uses 400 W of power when it’s running, and it runs 8 hours a day. What is the yearly cost of operating your refrigerator?

25.54 In the circuit shown in Fig. P25.54, R is a variable resistor whose value ranges from 0 to ∞, and a and b are the terminals of a battery that has an emf ϵ=15.0 V and an internal resistance of 4.00 Ω. The ammeter and voltmeter are idealized meters. As R varies over its full range of values, what will be the largest and smallest readings of (a) the voltmeter and (b) the ammeter? (c) Sketch qualitative graphs of the readings of both meters as functions of R.



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==> c16-20.txt <==
kirchhoff3.eps
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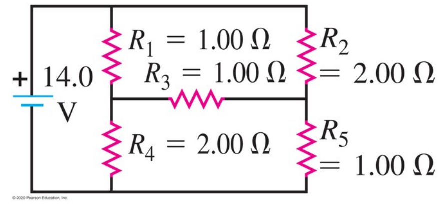
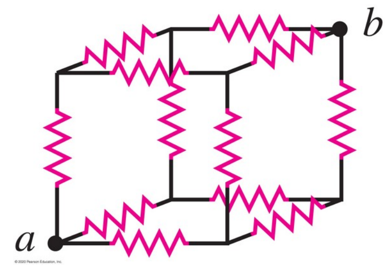
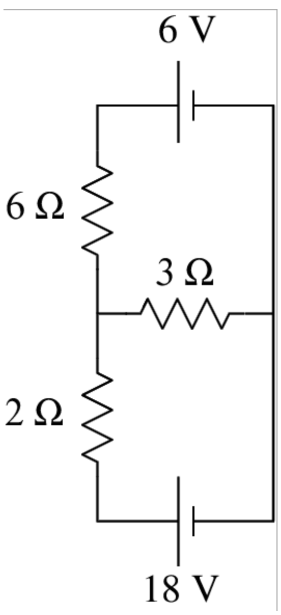
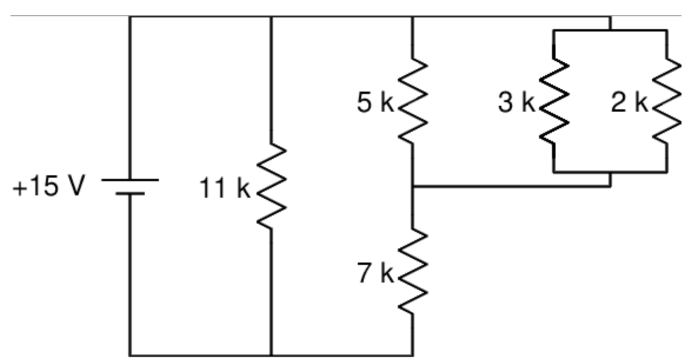


26.62 (a) Find the current through the battery and each resistor in the circuit shown in Fig. P26.62. (b) What is the equivalent resistance of the resistor network?

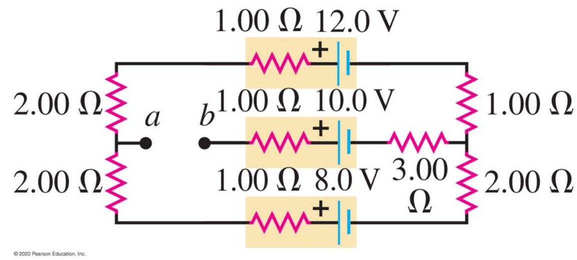
26.84 Suppose a resistor R lies along each edge of a cube (12 resistors in all) with connections at the corners. Find the equivalent resistance between two diagonally opposite corners of the cube (points a and b in Fig. P26.84).



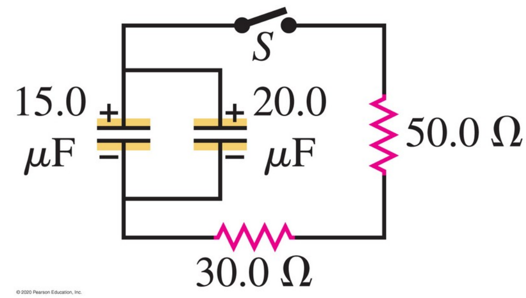




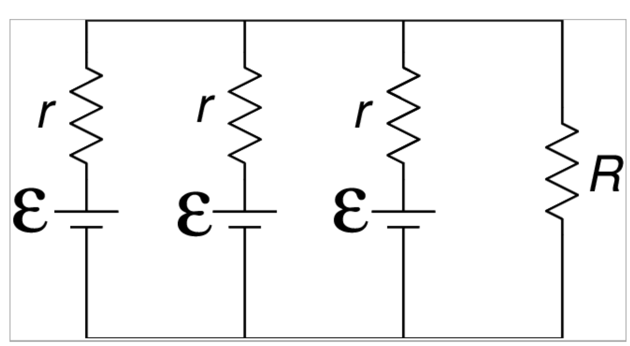
==> c17-20.txt <==
3battery_parallel_r.eps



26.57 (a) Find the potential of point a with respect to point b in Fig. P26.57. (b) If points a and b are connected by a wire with negligible resistance, find the current in the 12.0 V battery.

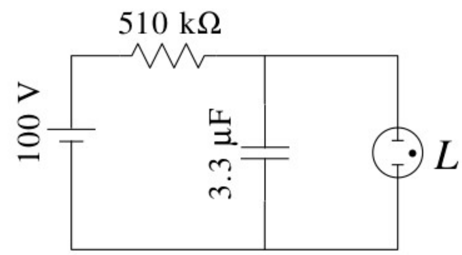


26.41 CP In the circuit shown in Fig. E26.41 both capacitors are initially charged to 45.0 V. (a) How long after closing the switch S will the potential across each capacitor be reduced to 10.0 V, and (b) what will be the current at that time?



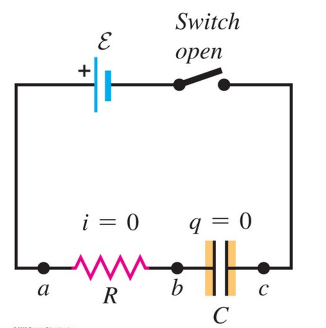
==> c18-20.txt <==

15. In the circuit shown, E = 100 V, R = 510 kΩ, and C = 3.3 μF. The neon lamp L is generally a non-conductor, however, when the voltage across it exceeds 45 V it flashes for an instant (and during that instant it conducts like a wire). What is the time interval between flashes? If all the energy stored in the capacitor just before the flash is dissipated in the neon lamp, what is the average power dissipated in the neon lamp over the cycle?



26.38 You connect a battery, resistor, and capacitor as in Fig. 26.20a, where ϵ=36.0 V, C=5.00 μF, and R=120 Ω. The switch S is closed at t=0. (a) When the voltage across the capacitor is 8.00 V, what is the magnitude of the current in the circuit? (b) At what time t after the switch is closed is the voltage across the capacitor 8.00 V? (c) When the voltage across the capacitor is 8.00 V, at what rate is energy being stored in the capacitor?

(a) Capacitor initially uncharged



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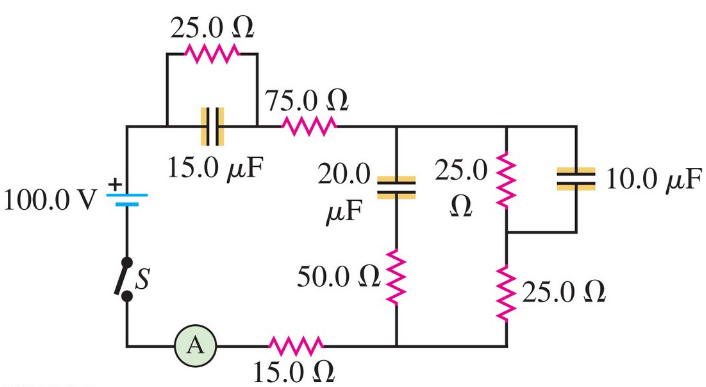
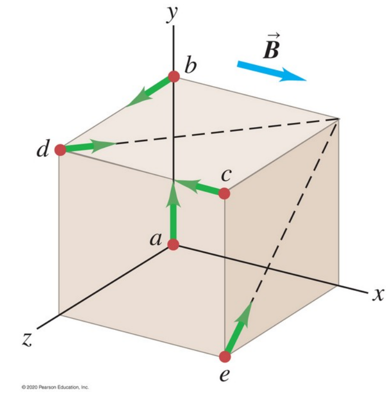
26.47 In the circuit in Fig. E26.47 the capacitors are initially uncharged, the battery has no internal resistance, and the ammeter is idealized. Find the ammeter reading (a) just after the switch S is closed and (b) after S has been closed for a very long time.



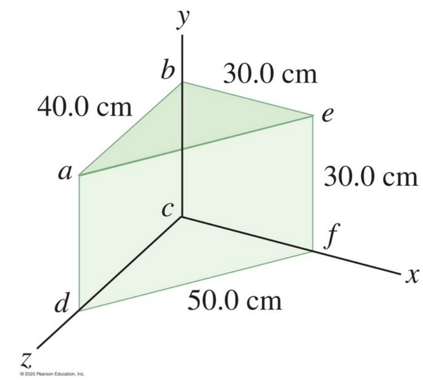
==> c21-20.txt <==

Q27.12 Each of the lettered points at the corners of the cube in Fig. Q27.12 represents a positive charge q moving with a velocity of magnitude υ in the direction indicated. The region in the figure is in a uniform magnetic field $\vec{B}$, parallel to the x−axis and directed toward the right. Which charges experience a force due to $\vec{B}$? What is the direction of the force on each charge?



27.4 A particle with mass 1.81×10^−3 kg and a charge of 1.22 × 10^−8 C has, at a given instant, a velocity υ=(4.19×10^4 i − 3.85×10^4 j) m/s.
What are the magnitude and direction of the particle’s acceleration produced by a uniform magnetic field B=(1.63 i + 0.980 j) T?

27.13 The magnetic field $\vec{B}$ in a certain region is 0.128 T, and its direction is that of the +z-axis in Fig. E27.13. (a) What is the magnetic flux across the surface abcd in the figure? (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?



27.16 • An alpha particle (a He nucleus, containing two protons and two neutrons and having a mass of 6.64×10^−27 kg) traveling horizontally at 35.6 km/s enters a uniform, vertical, 1.80 T magnetic field. (a) What is the diameter of the path followed by this alpha particle? (b) What effect does the magnetic field have on the speed of the particle? (c) What are the magnitude and direction of the acceleration of the alpha particle while it is in the magnetic field? (d) Explain why the speed of the particle does not change even though an unbalanced external force acts on it.

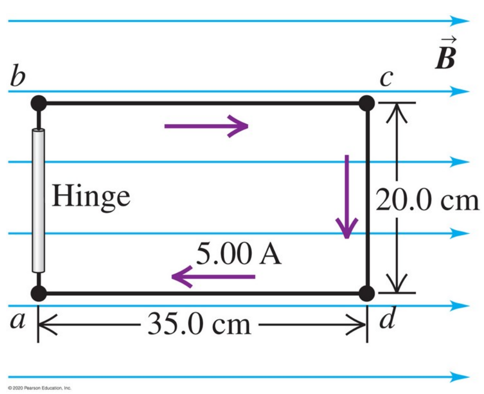
==> c22-20.txt <==
27.18 BIO Cyclotrons are widely used in nuclear medicine for producing short-lived radioactive isotopes. These cyclotrons typically accelerate H− (the hydride ion, which has one proton and two electrons) to an energy of 5 MeV to 20 MeV. This ion has a mass very close to that of a proton because the electron mass is negligible—about 1/2000 of the proton's mass. A typical magnetic field in such cyclotrons is 1.9 T. (a) What is the speed of a 5.0 MeV H−? (b) If the H− has energy 5.0 MeV and B=1.9 T, what is the radius of this ion's circular orbit?

$M_p = 1.6726 \times 10^{-27}$ kg 1 eV = 1.6022×10^{-19} J

27.30 A straight, 2.5 m wire carries a typical household current of 1.5 A (in one direction) at a location where the earth's magnetic field is 0.55 gauss from south to north. Find the magnitude and direction of the force that our planet's magnetic field exerts on this wire if it is oriented so that the current in it is running (a) from west to east, (b) vertically upward, (c) from north to south. (d) Is the magnetic force ever large enough to cause significant effects under normal household conditions?

27.32 An electromagnet produces a magnetic field of 0.550 T in a cylindrical region of radius 2.50 cm between its poles. A straight wire carrying a current of 10.8 A passes through the center of this region and is perpendicular to both the axis of the cylindrical region and the magnetic field. What magnitude of force does this field exert on the wire?

27.37 The 20.0 cm×35.0 cm rectangular circuit shown in Fig. E27.37 is hinged along side ab. It carries a clockwise 5 A current and is located in a uniform 1.20 T magnetic field oriented perpendicular to two of its sides, as shown. (a) Draw a clear diagram showing the direction of the force that the magnetic field exerts on each segment of the circuit (ab, bc, etc.). (b) Of the four forces you drew in part (a), decide which ones exert a torque about the hinge ab. Then calculate only those forces that exert this torque. (c) Use your results from part (b) to calculate the torque that the magnetic field exerts on the circuit about the hinge axis ab.



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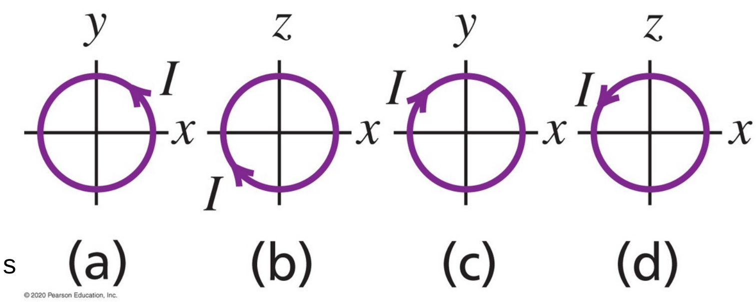
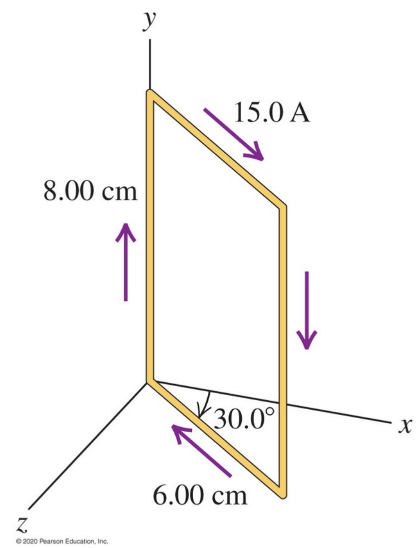
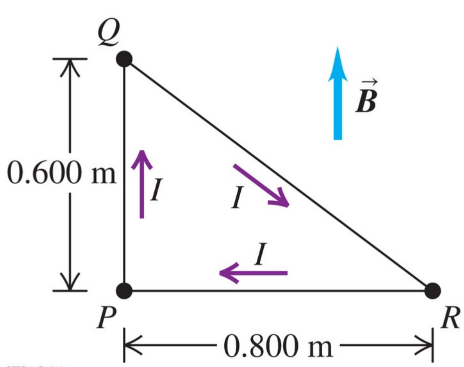


27.41 A circular coil with area A and N turns is free to rotate about a diameter that coincides with the x-axis. Current I is circulating in the coil. There is a uniform magnetic field $\vec{B}$ in the positive y-direction. Calculate the magnitude and direction of the torque $\vec{\tau}$ and the value of the potential energy U, as given in Eq. (27.27), when the coil is oriented as shown in parts (a) through (d) of Fig. E27.41.



27.64 The rectangular loop shown in Fig. P27.64 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?

27.67 The loop of wire shown in Fig. P27.67 forms a right triangle and carries a current I=5.00 A in the direction shown. The loop is in a uniform magnetic field that has magnitude B=3.00 T and the same direction as the current in side PQ of the loop. (a) Find the force exerted by the magnetic field on each side of the triangle. If the force is not zero, specify its direction. (b) What is the net force on the loop? (c) The loop is pivoted about an axis that lies along side PR. Use the forces calculated in part (a) to calculate the torque on each side of the loop (see Problem 27.66). (d) What is the magnitude of the net torque on the loop? Calculate the net torque from the torques calculated in part (c) and also from Eq. (27.28). Do these two results agree? (e) Is the net torque directed to rotate point Q into the plane of the figure or out of the plane of the figure?



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==> c24-20.txt <==
28.9 A straight wire carries a 10.0 A current (Fig. E28.9).
ABCD is a rectangle with point D in the middle of a 1.10 mm
segment of the wire and point C in the wire. Find the
magnitude and direction of the magnetic field due to this
segment at (a) point A; (b) point B; (c) point C.
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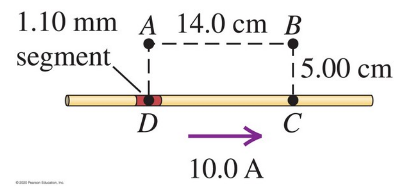


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28.21 Two long, straight, parallel wires, 10.0 cm apart,
carry equal 4.00 A currents in the same direction, as shown
in Fig. E28.21. Find the magnitude and direction of the
magnetic field at (a) point P1, midway between the wires;
(b) point P2, 25.0 cm to the right of P1; (c) point P3,
20.0 cm directly above P1.
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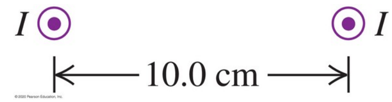


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28.23 Four long, parallel power lines each carry 100 A
currents. A cross-sectional diagram of these lines is a
square, 20.0 cm on each side. For each of the three cases
shown in Fig. E28.23, calculate the magnetic field at the
center of the square.
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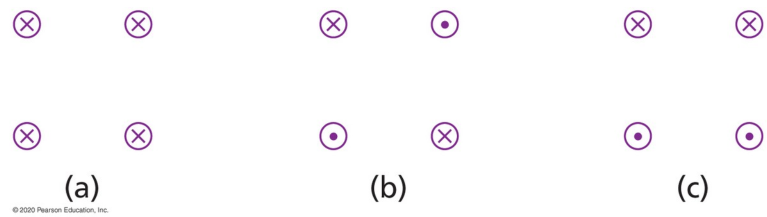


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28.25 Two very long insulated wires perpendicular to each
other in the same plane carry currents as shown in Fig.
E28.25. Find the magnitude of the net magnetic field these
wires produce at points P and Q if the 10.0 A current is (a)
to the right or (b) to the left.
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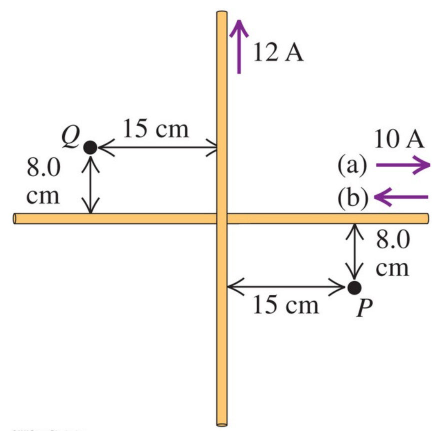

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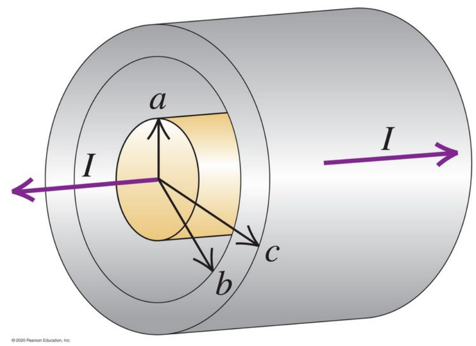
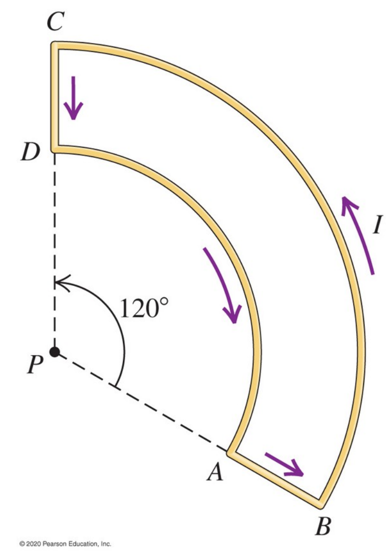
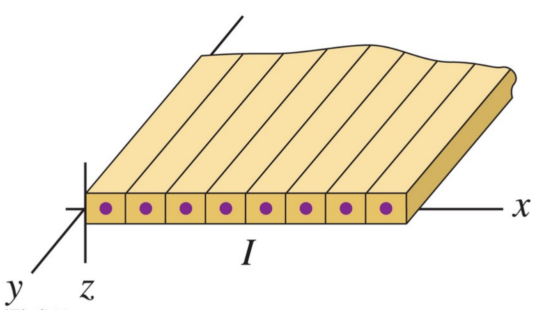
28.39 Coaxial Cable. A solid conductor with radius a is supported by insulating disks on the axis of a conducting tube with inner radius b and outer radius c (Fig. E28.39). The central conductor and tube carry equal currents I in opposite directions. The currents are distributed uniformly over the cross 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).



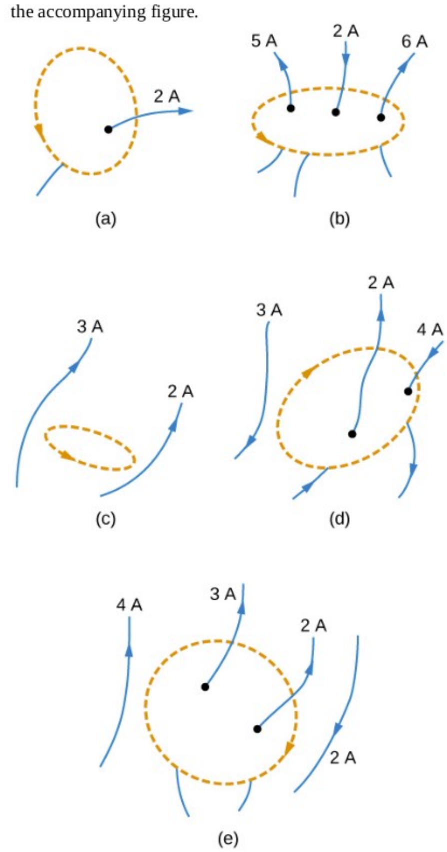
28.64 Calculate the magnetic field (magnitude and direction) at a point P due to a current I=12.0 A in the wire shown in Fig. P28.64. Segment BC is an arc of a circle with radius 30.0 cm, and point P is at the center of curvature of the arc. Segment DA is an arc of a circle with radius 20.0 cm, and point P is at its center of curvature. Segments CD and AB are straight lines of length 10.0 cm each.



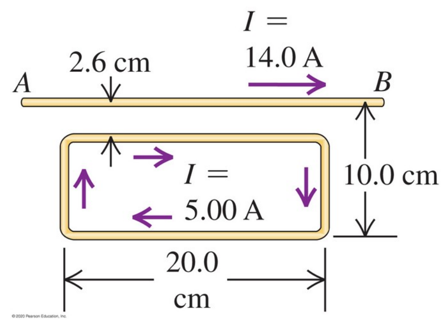
28.69 An Infinite Current Sheet. Long, straight conductors with square cross sections and each carrying current I are laid side by side to form an infinite current sheet (Fig. P28.69). The conductors lie in the xy-plane, are parallel to the y-axis, and carry current in the +y−direction. There are n conductors per unit length measured along the x−axis. (a) What are the magnitude and direction of the magnetic field a distance a below the current sheet? (b) What are the magnitude and direction of the magnetic field a distance a above the current sheet?



42. Evaluate $\oint \vec{\mathbf{B}} \cdot d\,\vec{\mathbf{l}}$ for each of the cases shown in the accompanying figure.

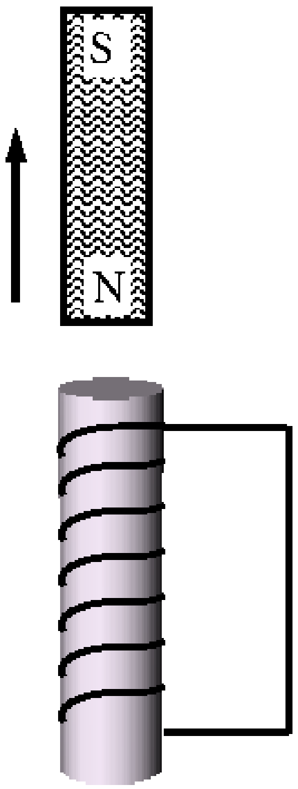


==> c26-20.txt <==
28.60 The long, straight wire AB shown in Fig. P28.60 carries a current of 14.0 A. The rectangular loop whose long edges are parallel to the wire carries a current of 5.00 A. Find the magnitude and direction of the net force exerted on the loop by the magnetic field of the wire.

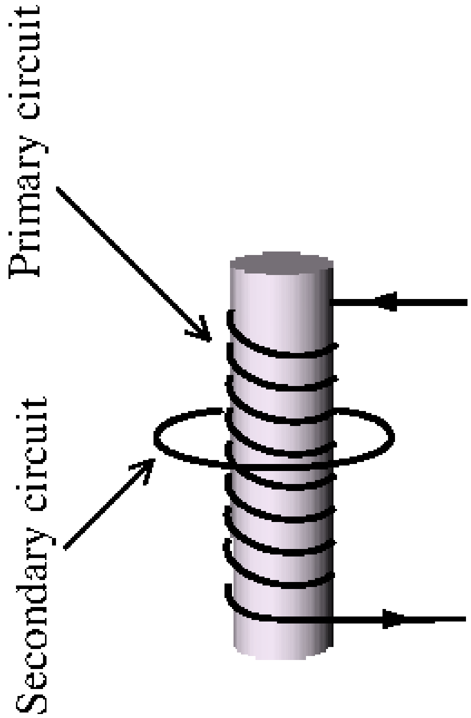


28.47 A long solenoid with 60 turns of wire per centimeter carries a current of 0.15 A. The wire that makes up the solenoid is wrapped around a solid core of silicon steel (K_m=5200). (The wire of the solenoid is jacketed with an insulator so that none of the current flows into the core.) (a) For a point inside the core, find the magnitudes of (i) the magnetic field $\vec{B}_0$ due to the solenoid current; (ii) the magnetization $\vec{M}$; (iii) the total magnetic field $\vec{B}$. (b) In a sketch of the solenoid and core, show the directions of the vectors $\vec{B}$, $\vec{B}_0$, and $\vec{M}$ inside the core.

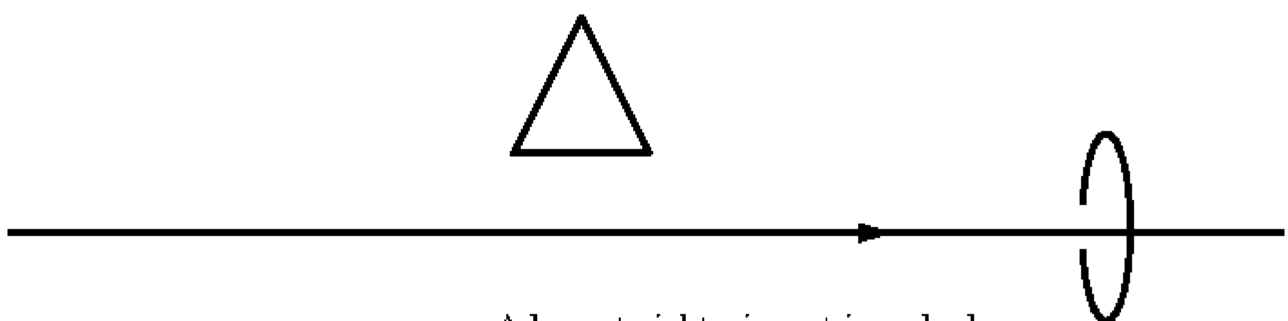
28.65 CALC A long, straight wire with a circular cross section of radius R carries a current I. Assume that the current density is not constant across the cross section of the wire, but rather varies as $J=\alpha r$, where α is a constant. (a) By the requirement that J integrated over the cross section of the wire gives the total current I, calculate the constant α in terms of I and R. (b) Use Ampere’s law to calculate the magnetic field B(r) for (i) $r \le R$ and (ii) $r \ge R$. Express your answers in terms of I.

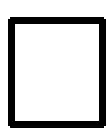


The north pole of a bar magnet is moving away from the solenoid



The current shown flowing through the primary circuit is increasing





A long straight wire, a triangular loop and a square loop of wire sit in the plane of this sheet of paper. A circular loop of wire is centered on the long wire, but sits in a plane perpendicular to the long wire. For several minutes there has been a current flowing to the right; that current is now decreasing.

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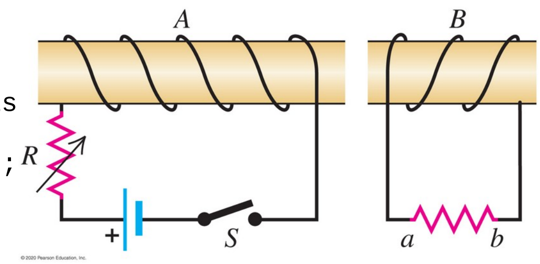
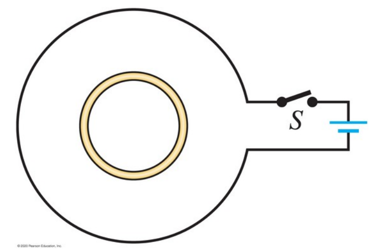
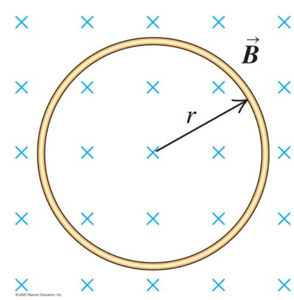


29.19 Using Lenz’s law, determine the direction of the current in resistor ab of Fig. E29.19 when (a) switch S is opened after having been closed for several minutes; (b) coil b is brought closer to coil A with the switch closed; (c) the resistance of R is decreased while the switch remains closed.

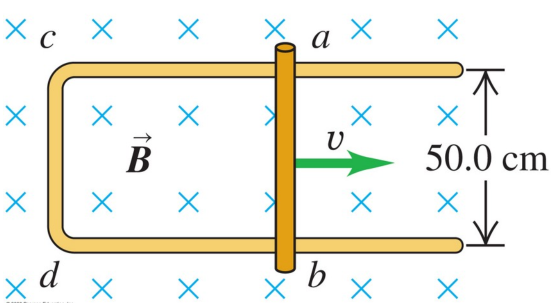


29.21 A small, circular ring is inside a larger loop that is connected to a battery and a switch (Fig. E29.21). Use Lenz’s law to find the direction of the current induced in the small ring (a) just after switch S is closed; (b) after S has been closed a long time; (c) just after S has been reopened after it was closed for a long time.



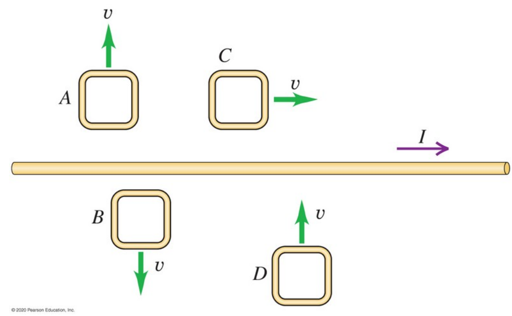
29.22 CALC A circular loop of wire with radius r=0.0250 m and resistance R=0.390 Ω is in a region of spatially uniform magnetic field, as shown in Fig. E29.22. The magnetic field is directed into the plane of the figure. At t=0, B=0. The magnetic field then begins increasing, with B(t) = (0.380 T/s^3)t^3. What is the current in the loop (magnitude and direction) at the instant when B=1.33 T?

29.27 The conducting rod ab shown in Fig. E29.27 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 abdc is 1.50 Ω (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 (Fυ) with the rate at which thermal energy is developed in the circuit (I^2 R).



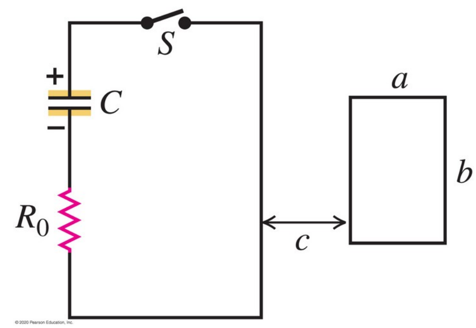
==> c28-20.txt <==
28.18 Two long, straight wires, one above the other, are separated by a distance 2a and are parallel to the x−axis. Let the +y−axis be in the plane of the wires in the direction from the lower wire to the upper wire. Each wire carries current I in the +x−direction. What are the magnitude and direction of the net magnetic field of the two wires at a point in the plane of the wires (a) midway between them; (b) at a distance a above the upper wire; (c) at a distance a below the lower wire?

29.16 The current I in a long, straight wire is constant and is directed toward the right as in Fig. E29.16. Conducting loops A, b, C, and D are moving, in the directions shown, near the wire. (a) For each loop, is the direction of the induced current clockwise or counterclockwise, or is the induced current zero? (b) For each loop, what is the direction of the net force that the wire exerts on the loop? Give your reasoning for each answer.

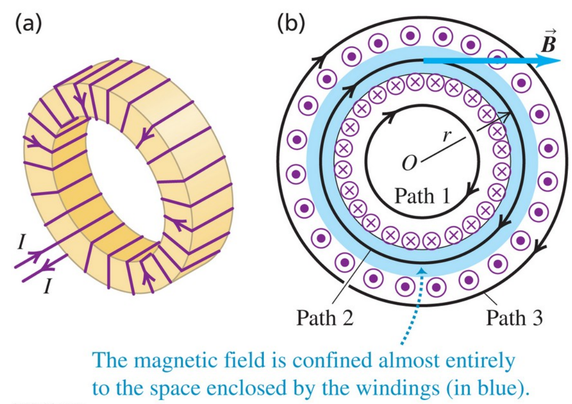


The magnetic field within a long, straight solenoid with a circular cross section and radius R is increasing at a rate of dB/dt. (a) What is the rate of change of flux through a circle with radius r1 inside the solenoid, normal to the axis of the solenoid, and with center on the solenoid axis? (b) Find the magnitude of the induced electric field inside the solenoid, at a distance r1 from its axis. Show the direction of this field in a diagram. (c) What is the magnitude of the induced electric field outside the solenoid, at a distance r2 from the axis? (d) Graph the magnitude of the induced electric field as a function of the distance r from the axis from r = 0 to r = 2R. (e) What is the magnitude of the induced emf in a circular turn of radius R/2 that has its center on the solenoid axis? (f) What is the magnitude of the induced emf if the radius in part (e) is R? (g) What is the induced emf if the radius in part (e) is 2R?

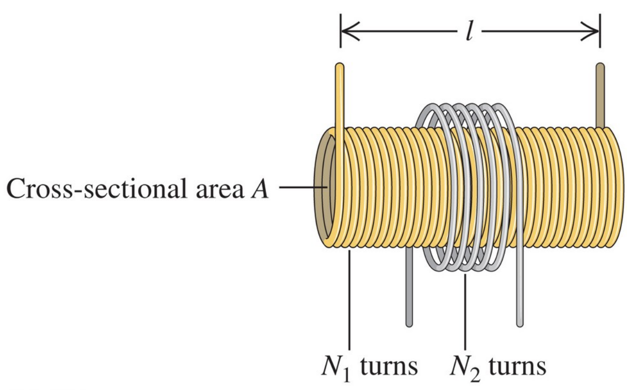
==> c29-20.txt <==
29.45 CP CALC In the circuit shown in Fig. P29.45, the capacitor has capacitance C=20 μF and is initially charged to 100 V with the polarity shown. The resistor R0 has resistance 10 Ω. At time t=0 the switch S is closed. The small circuit is not connected in any way to the large one. The wire of the small circuit has a resistance of 1.0 Ω/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 cm and b=20.0 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 Exercise 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.



Example 28.10 Field of a toroidal solenoid Figure 28.25a shows a doughnut-shaped toroidal solenoid, tightly wound with N turns of wire carrying a current I. (In a practical solenoid the turns would be much more closely spaced than they are in the figure.) Find the magnetic field at all points.



Example 30.1 Calculating mutual inductance In one form of Tesla coil (a high-voltage generator popular in science museums), a long solenoid with length l and cross-sectional area A is closely wound with N1 turns of wire. A coil with N2 turns surrounds it at its center (Fig. 30.3). Find the induced emf in 2 due to a changing current in 1



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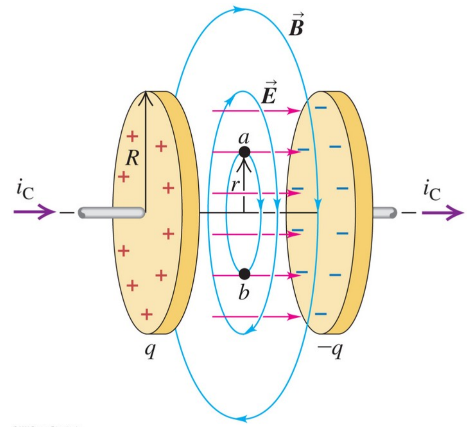
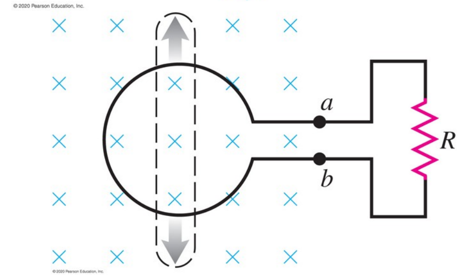
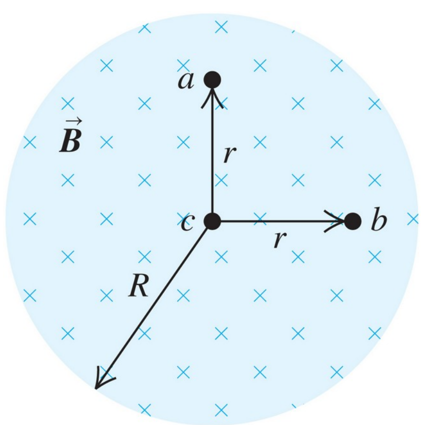
29.38 A parallel-plate, air-filled capacitor is being charged as in Fig. 29.23. The circular plates have radius 4.00 cm, and at a particular instant the conduction current in the wires is 0.520 A. (a) What is the displacement current density jD in the air space between the plates? (b) What is the rate 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?



29.51 A flexible circular loop 6.50 cm in diameter lies in a magnetic field with magnitude 1.35 T, directed into the plane of the page as shown in Fig. P29.51. The loop is pulled at the points indicated by the arrows, forming a loop of zero area in 0.250 s. (a) Find the average induced emf in the circuit. (b) What is the direction of the current in R: from a to b or from b to a? Explain your reasoning.



29.61 The magnetic field $\vec{B}$, at all points within a circular region of radius R, is uniform in space and directed into the plane of the page as shown in Fig. P29.61. (The region could be a cross section inside the windings of a long, straight solenoid.) If the magnetic field is increasing at a rate dB/dt, what are the magnitude and direction of the force on a stationary positive point charge q located at points a, b, and c? (Point a is a distance R above the center of the region, point b is a distance R to the right of the center, and point c is at the center of the region.)



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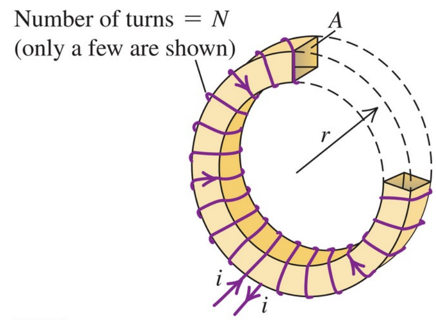
Example 30.3 Determine the self-inductance of a toroidal solenoid with cross-sectional area A and mean radius r, closely wound with N1 turns of wire on a nonmagnetic core (Fig. 30.8). Assume that B is uniform across a cross section (that is, neglect the variation of B with distance from the toroid axis). A second toroidal solenoid with N2 turns is wound uniformly on top of the first, so that that the two solenoids have the same cross-sectional area and mean radius. What is the mutual inductance?



30.6 A toroidal solenoid has 500 turns, cross-sectional area 6.25 cm^2, and mean radius 4.00 cm. (a) Calculate the coil’s self-inductance. (b) If the current decreases uniformly from 5.00 A to 2.00 A in 3.00 ms, calculate the self-induced emf in the coil. (c) The current is directed from terminal a of the coil to terminal b. Is the direction of the induced emf from a to b or from b to a?

(a) 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=μ0AN^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.) (b) A metallic laboratory spring is typically 5.00 cm long and 0.150 cm in diameter and has 50 coils. If you connect such a spring in an electric circuit, how much self-inductance must you include for it if you model it as an ideal solenoid?

30.18 It has been proposed to use large inductors as energy storage devices. (a) How much electrical energy is converted to light and thermal energy by a 150 W light bulb in one day? (b) If the amount of energy calculated in part (a) is stored in an inductor in which the current is 80.0 A, what is the inductance?

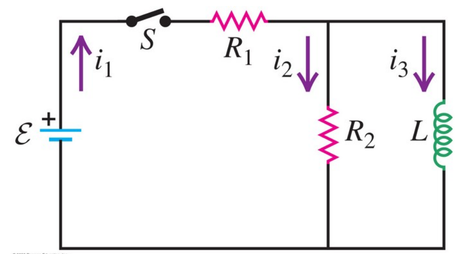
==> c33-20.txt <==
30.21 An inductor with an inductance of 2.50 H and a resistance of 8.00 Ω is connected to the terminals of a battery with an emf of 6.00 V and negligible internal resistance. Find (a) the initial rate of increase of current in the circuit; (b) the rate of increase of current at the instant when the current is 0.500 A; (c) the current 0.250 s after the circuit is closed; (d) the final steady-state current.

30.30 Consider the circuit in Exercise 30.21. (a) Just after the circuit is completed, at what rate is the battery supplying electrical energy to the circuit? (b) When the current has reached its final steady-state value, how much energy is stored in the inductor? What is the rate at which electrical energy is being dissipated in the resistance of the inductor? What is the rate at which the battery is supplying electrical energy to the circuit?

30.46 CP CALC 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 dΦB 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 μ0 2π ln(b/a) (e) Use Eq. (30.9) to calculate the energy stored in the magnetic field for a length l of the cable.

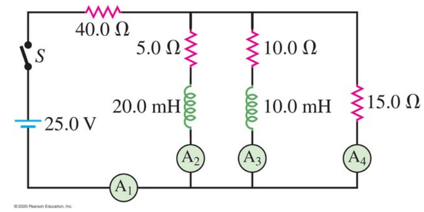
==> c34-20.txt <==
30.35 • L-C Oscillations. A capacitor with capacitance 6.00×10^{-5} F is charged by connecting it to a 12.0 V battery. The capacitor is disconnected from the battery and connected across an inductor with L=1.50 H. (a) What are the angular frequency ω of the electrical oscillations and the period of these oscillations (the time for one oscillation)? (b) What is the initial charge on the capacitor? (c) How much energy is initially stored in the capacitor? (d) What is the charge on the capacitor 0.0230 s after the connection to the inductor is made? Interpret the sign of your answer. (e) At the time given in part (d), what is the current in the inductor? Interpret the sign of your answer. (f) At the time given in part (d), how much electrical energy is stored in the capacitor and how much is stored in the inductor?

30.52 CALC An inductor with inductance L=0.200 H and negligible resistance is connected to a battery, a switch S, and two resistors, R1=8.00 Ω and R2=6.00 Ω (Fig. P30.52). The battery has emf 48.0 V and negligible internal resistance. S is closed at t=0. (a) What are the currents i1, i2, and i3 just after S is closed? (b) What are i1, i2, and i3 after S has been closed a long time? (c) Apply Kirchhoff’s rules to the circuit and obtain a differential equation for i3(t). Integrate this equation to obtain an equation for i3 as a function of the time t that has elapsed since S was closed. (d) Use the equation that you derived in part (c) to calculate the value of t for which i3 has half of the final value that you calculated in part (b). (e) When i3 has half of its final value, what are i1 and i2?

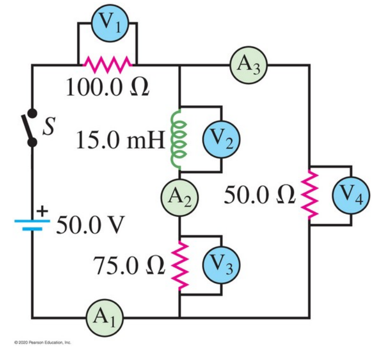


==> c35-20.txt <==

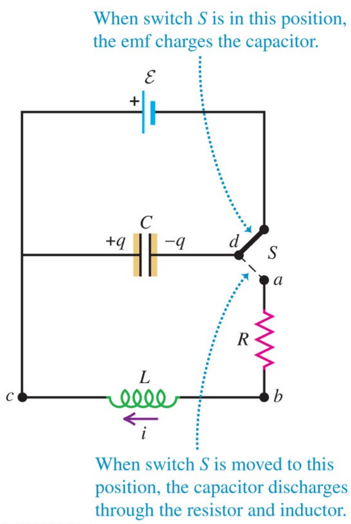
30.65 CP In the circuit shown in Fig. P30.65, switch S is closed at time t=0. (a) Find the reading of each meter just after S is closed. (b) What does each meter read long after S is closed?



30.58 CP In the circuit shown in Fig. P30.58, 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.



30.38 For the circuit of Fig. 30.17, let C=15.0 nF, L=22 mH, and R=75.0 Ω. (a) Calculate the oscillation frequency of the circuit once the capacitor has been charged and the switch has been connected to point a. (b) How long will it take for the amplitude of the oscillation to decay to 10.0% of its original value? (c) What value of R would result in a critically damped circuit?



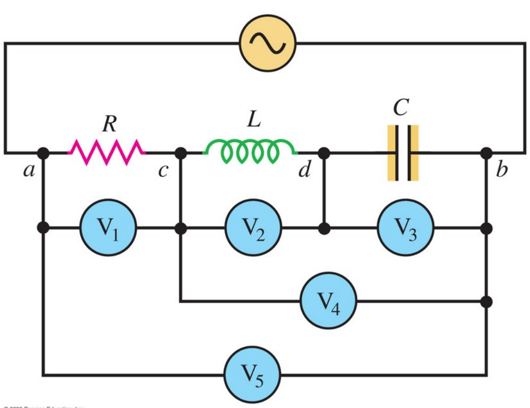
==> c36-20.txt <==
31.5 (a) What is the reactance of a 3.00 H inductor at a frequency of 80.0 Hz? (b) What is the inductance of an inductor whose reactance is 120 Ω at 80.0 Hz? (c) What is the reactance of a 4.00 μF capacitor at a frequency of 80 Hz? (d) What is the capacitance of a capacitor whose reactance is 120 Ω at 80.0 Hz?

What is the maximum current delivered to a circuit containing a 1.40 μF capacitor when it is connected across the following outlets? (a) a North American outlet having Vrms = 120 V, f = 60.0 Hz (b) a European outlet having Vrms = 240 V and f = 50.0 Hz. mA

As a way of determining the inductance of a coil used in a research project, a student first connects the coil to a 12.0 V battery and measures a current of 0.630 A. The student then connects the coil to a 24.0 V (RMS), 60.0 Hz generator and measures an RMS current of 0.570 A. What is the inductance?

31.12 You have a 200 Ω resistor, a 0.400 H inductor, and a 6.00 μF capacitor. Suppose you take the resistor and inductor and make a series circuit with a voltage source that has voltage amplitude 30.0 V and an angular frequency of 250 rad/s. (a) What is the impedance of the circuit? (b) What is the current amplitude? (c) What are the voltage amplitudes across the resistor and across the inductor? (d) What is the phase angle ϕ of the source voltage with respect to the current? Does the source voltage lag or lead the current? (e) Construct the phasor diagram.

31.40 Five infinite-impedance voltmeters, calibrated to read rms values, are connected as shown in Fig. P31.40. Let R=200 Ω, L=0.400 H, C=6.00 μF, and V=30.0 V. What is the reading of each voltmeter if (a) ω=200 rad/s and (b) ω=1000 rad/s?



==> c37-20.txt <==
31.18 A resistor with $R=300\ \Omega$ and an inductor are connected in series across an ac source that has voltage amplitude 500 V. The rate at which electrical energy is dissipated in the resistor is 286 W. What is (a) the impedance Z of the circuit; (b) the amplitude of the voltage across the inductor; (c) the power factor?

31.23 An L-R-C series circuit with $L=0.120$ H, $R=240\ \Omega$, and $C=7.30\ \mu F$ carries an rms current of 0.450 A with a frequency of 400 Hz. (a) What are the phase angle and power factor for this circuit? (b) What is the impedance of the circuit? (c) What is the rms voltage of the source? (d) What average power is delivered by the source? (e) What is the average rate at which electrical energy is converted to thermal energy in the resistor? (f) What is the average rate at which electrical energy is dissipated (converted to other forms) in the capacitor? (g) In the inductor?

31.28 An L-R-C series circuit is constructed using a $175\ \Omega$ resistor, a $12.5\ \mu F$ capacitor, and an 8.00 mH inductor, all connected across an ac source having a variable frequency and a voltage amplitude of 25.0 V. (a) At what angular frequency will the impedance be smallest, and what is the impedance at this frequency? (b) At the angular frequency in part (a), what is the maximum current through the inductor? (c) At the angular frequency in part (a), find the potential difference across the ac source, the resistor, the capacitor, and the inductor at the instant that the current is equal to one-half its greatest positive value. (d) In part (c), how are the potential differences across the resistor, inductor, and capacitor related to the potential difference across the ac source?

31.45 In an L-R-C series circuit, $R=300\ \Omega$, $XC=300\ \Omega$, and $XL=500\ \Omega$. The average electrical power consumed in the resistor is 60.0 W. (a) What is the power factor of the circuit? (b) What is the rms voltage of the source?

==> c38-20.txt <==
31.26 In an L-R-C series circuit the source is operated at its resonant angular frequency. At this frequency, the reactance XC of the capacitor is 200 Ω and the voltage amplitude across the capacitor is 600 V. The circuit has R=300 Ω. What is the voltage amplitude of the source?

31.36 A Step-Up Transformer. A transformer connected to a 120 V (rms) ac line is to supply 13,000 V (rms) for a neon sign. To reduce shock hazard, a fuse is to be inserted in the primary circuit; the fuse is to blow when the rms current in the secondary circuit exceeds 8.50 mA. (a) What is the ratio of secondary to primary turns of the transformer? (b) What power must be supplied to the transformer when the rms secondary current is 8.50 mA? (c) What current rating should the fuse in the primary circuit have?

A large power plant generates electricity at 12.0 kV. Its old transformer once converted the voltage to 335 kV. The secondary of this transformer is being replaced so that its output can be 750 kV for more efficient cross-country transmission on upgraded transmission lines. (a) What is the ratio of turns in the new secondary compared with the old secondary? (b) What is the ratio of new current output to old output (at 335 kV) for the same power? (c) If the upgraded transmission lines have the same resistance, what is the ratio of new line power loss to old? If the power output is 1000 MW and the line resistance is 2 Ω, where were the old and new line losses?

==> c39-20.txt <==
32.6 BIO Ultraviolet Radiation. There are two categories of ultraviolet light. Ultraviolet A (UVA) has a wavelength ranging from 320 nm to 400 nm. It is necessary for the production of vitamin D. UVB, with a wavelength in vacuum between 280 nm and 320 nm, is more dangerous because it is much more likely to cause skin cancer. (a) Find the frequency ranges of UVA and UVB. (b) What are the ranges of the wave numbers for UVA and UVB?

32.8 An electromagnetic wave of wavelength 435 nm is traveling in vacuum in the $-z$-direction. The electric field has amplitude 2.70×10^{-3} V/m and is parallel to the x-axis. What are (a) the frequency and (b) the magnetic-field amplitude? (c) Write the vector equations for $\vec{E}(z, t)$ and $\vec{B}(z, t)$.

32.9 An electromagnetic wave has an electric field given by $E(y, t)=(3.10\times10^{5}\ \mathrm{V/m})k\cos[ky-(12.65\times10^{12}\ \mathrm{rad/s})t]$.
(a) In which direction is the wave traveling? (b) What is the wavelength of the wave? (c) Write the vector equation for $\vec{B}(y, t)$.

32.11 Radio station WCCO in Minneapolis broadcasts at a frequency of 830 kHz. At a point some distance from the transmitter, the magnetic-field amplitude of the electromagnetic wave from WCCO is 4.82×10^{-11} T. Calculate (a) the wavelength; (b) the wave number; (c) the angular frequency; (d) the electric-field amplitude.

==> c40-20.txt <==
32.13 An electromagnetic wave with frequency 5.70×10^{14} Hz propagates with a speed of 2.17×10^{8} 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.

32.22 Television Broadcasting. Public television station KQED in San Francisco broadcasts a sinusoidal radio signal at a power of 777 kW. Assume that the wave spreads out uniformly into a hemisphere above the ground. At a home 5 km away from the antenna, (a) what average pressure does this wave exert on a totally reflecting surface, (b) what are the amplitudes of the electric and magnetic fields of the wave, and (c) what is the average density of the energy this wave carries? (d) For the energy density in part (c), what percentage is due to the electric field and what percentage is due to the magnetic field?

32.40 CP A circular wire loop has a radius of 7.50 cm. A sinusoidal electromagnetic plane wave traveling in air passes through the loop, with the direction of the magnetic field of the wave perpendicular to the plane of the loop. The intensity of the wave at the location of the loop is 0.0275 W/m^2, and the wavelength of the wave is 6.90 m. What is the maximum emf induced in the loop?

32.39 CP CALC 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.

==> c41-20.txt <==

32.51 CP Electromagnetic radiation is emitted by accelerating charges. The rate at which energy is emitted from an accelerating charge that has charge q and acceleration a is given by

$dE/dt=q^2 a^2/ 6\pi\epsilon_0 c^3$

where c is the speed of light. (a) Verify that this equation is dimensionally correct. (b) If a proton with a kinetic energy of 6.0 MeV is traveling in a particle accelerator in a circular orbit of radius 0.750 m, what fraction of its energy does it radiate per second? (c) Consider an electron orbiting with the same speed and radius. What fraction of its energy does it radiate per second?

Unit Check: Show that

μ_0/ϵ_0 has units of Ω^2

The square root of μ_0/ϵ_0 is called the impedance of free space and has value 377 Ω