30.53) To see why charge density and electric field are larger at the sharp corners of a conductor, consider two metal spheres of radii \( r_1 = R \) and \( r_2 = 2R \), both charged to the same potential \( V_0 \).

a. What is the ratio \( \eta_1/\eta_2 \) of their surface charge densities?

b. What is the ratio \( E_1/E_2 \) of the electric field strengths at their surfaces?

30.56) A spherical capacitor with a 1.0 mm gap between the spheres has a capacitance of 100 pF. What are the diameters of the two spheres?

30.65) Six identical capacitors with capacitance \( C \) are connected as shown in figure:

![Diagram of capacitors connected in series and parallel](image)

a. What is the equivalent capacitance of these six capacitors?

b. What is the potential difference between points \( a \) and \( b \)?

30.69) Capacitors \( C_1 = 10 \ \mu F \) and \( C_2 = 20 \ \mu F \) are each charged to 10V, then disconnected from the battery without changing the charge on the capacitor plates. The two capacitors are then connected in parallel with the positive plate of \( C_1 \) connected to the negative plate of \( C_2 \) and vice versa. Afterward, what are the charge on and the potential difference across each capacitor?

31.37) The resistance of a very fine aluminum wire with a 10 µm x 10 µm square cross section is 1000 Ω.

a. How long is the wire?

b. A 1000 Ω resistor is made by wrapping this wire in a spiral around a 3.0-mm-diameter glass core. How many turns of wire are needed?

31.46) The biochemistry that takes place inside cells depends on various elements, such as sodium, potassium, and calcium, that are dissolved in water as ions. These ions enter cells through narrow pores in the cell membrane known as ion channels. Each ion channel, which is formed from a specialized protein molecule, is selective for one type of ion. Measurements with microelectrodes have shown that a 0.30-nm-diameter potassium ion (\( K^+ \)) channel carries a current of 1.8 pA.

a. How many potassium ions pass through if the ion channel opens for 1.0 ms?
b. What is the current density in the ion channel?

31.50)
You need to design a 1.0 A fuse that "blows" if the current exceeds 1.0 A. The fuse material in your stockroom melts at a current density of 500 A/cm$^2$. What diameter wire of this material will do the job?

31.68)
You've decided to protect your house by placing a 5.0-m-tall iron lightning rod next to the house. The top is sharpened to a point and the bottom is in good contact with the ground. From your research, you've learned that lightning bolts can carry up to 50 kA of current and last up to 50 μs.

a. How much charge is delivered by a lightning bolt with these parameters?
b. You don't want the potential difference between the top and bottom of the lightning rod to exceed 100 V. What is the minimum diameter, in cm, the rod can be?

32.55)
For an ideal battery ($r = 0$ Ω), closing the switch in figure does not affect the brightness of bulb A. In practice, bulb A dims *just a little* when the switch closes. To see why, assume that the 1.50 V battery has an internal resistance $r = 0.50$ Ω and that the resistance of a glowing bulb is $R = 6.00$ Ω.

![Image](image_url)

a. What is the current through bulb A when the switch is open?
b. What is the current through bulb A after the switch has closed?
c. By what percentage does the current through A change when the switch is closed?

32.63)
For the circuit shown in the figure, find the current through and the potential difference across each resistor. Place your results in a table for ease of reading.
32.68) A 12 V car battery dies not so much because its voltage drops but because chemical reactions increase its internal resistance. A good battery connected with jumper cables can both start the engine and recharge the dead battery. Consider the automotive circuit of the figure.

![Circuit Diagram]

a. How much current could the good battery alone drive through the starter motor?

b. How much current is the dead battery alone able to drive through the starter motor?

c. With the jumper cables attached, how much current passes through the starter motor?

d. With the jumper cables attached, how much current passes through the dead battery, and in which direction?

32.73) The capacitor in the figure begins to charge after the switch closes at t = 0 s.

![Circuit Diagram]

a. What is ΔV_C a very long time after the switch has closed?

b. What is Q_{max} in terms of E, R, and C?

c. In this circuit, does I=+dQ/dt or −dQ/dt? Explain.

d. Find an expression for the current I at time t. Graph I from t = 0 to t=5τ.

33.37) The two 10-cm-long parallel wires in the figure are separated by 5.0 mm. For what value of the resistor R will the force between the two wires be 5.4 X 10^{-5} N?
33.64) The figure shows a mass spectrometer, an analytical instrument used to identify the various molecules in a sample by measuring their charge-to-mass ratio $e/m$. The sample is ionized, the positive ions are accelerated (starting from rest) through a potential difference $\Delta V$, and they enter a region of uniform magnetic field. The field bends the ions into circular trajectories, but after just half a circle they either strike the wall or pass through a small opening to a detector. As the accelerating voltage is slowly increased, different ions reach the detector and are measured. Typical design values are a magnetic field strength $B = 0.200 \text{ T}$ and a spacing between the entrance and exit holes $d = 8.00 \text{ cm}$. What accelerating potential difference $\Delta V$ is required to detect (a) $\text{N}_2^+$, (b) $\text{O}_2^+$, and (c) $\text{CO}^+$? The accuracy of your answers should reflect the accuracy of the data. (For this problem, assume that all the data you need are good to six significant figures. Although $\text{N}_2^+$ and $\text{CO}^+$ both have a nominal molecular mass of 28, they are easily distinguishable in a cyclotron). The atomic mass of $^{12}\text{C} = 12.0000\text{u}$, for $^{14}\text{N} = 14.0031\text{u}$, $^{16}\text{O} = 15.9949\text{u}$.

33.66) The 10-turn loop of wire shown in the figure lies in a horizontal plane, parallel to a uniform horizontal magnetic field, and carries a 2.0 A current. The loop is free to rotate about a nonmagnetic axle through the center. A 50 g mass hangs from one edge of the loop. What magnetic field strength will prevent the loop from rotating about the axle?

33.68) A conducting bar of length $l$ and mass $m$ rests at the left end of the two frictionless rails of length $d$ in the figure. A uniform magnetic field of strength $B$ points upward.
a. In which direction, into or out of the page, will a current through the conducting bar cause the bar to experience a force to the right?
b. Find an expression for the bar's speed as it leaves the rails at the right end.

34.38)
The rectangular loop in the figure has 0.020 $\Omega$ resistance. What is the induced current in the loop at this instant?

34.43)
A loop antenna, such as is used on a television to pick up UHF broadcasts, is 25 cm in diameter. The plane of the loop is perpendicular to the oscillating magnetic field of a 150 MHz electromagnetic wave. The magnetic field through the loop is $B = (20 \text{ nT}) \sin(\omega t)$.

a. What is the maximum emf induced in the antenna?
b. What is the maximum emf if the loop is turned 90° to be perpendicular to the oscillating electric field?

34.76)
The switch in the figure has been in position 1 for a long time. It is changed to position 2 at $t = 0$ s.
a. What is the maximum current through the inductor?
b. What is the first time at which the current is maximum?

34.79) The switch in the figure has been open for a long time. It is closed at $t = 0$ s. What is the current through the 20 $\Omega$ resistor?
a. immediately after the switch is closed?
b. after the switch has been closed a long time?
c. immediately after the switch is reopened?

35.33) A very long 1.0-mm-diameter wire carries a 2.5 A current from left to right. Thin plastic insulation on the wire is positively charged with linear charge density 2.5 nC/cm. A mosquito 1.0 cm from the center of the wire would like to move in such a way as to experience an electric field but no magnetic field. How fast and which direction should she fly?

35.45) A cube of water 10 cm on a side is placed in a microwave beam having $E_0 = 11$ kV/m. The microwaves illuminate one face of the cube, and the water absorbs 80% of the incident energy. How long will it take to raise the water temperature by 50°C? Assume that the water has no heat loss during this time.

35.55) An 80 kg astronaut has gone outside his space capsule to do some repair work. Unfortunately, he forgot to lock his safety tether in place, and he has drifted 5.0 m away from the capsule. Fortunately, he has a 1000 W portable laser with fresh batteries that will operate it for 1.0 hr. His only chance is to accelerate himself toward the space capsule by firing the laser in the opposite direction. He has a 10-hr supply of oxygen. Can he make it?

35.56) Unpolarized light of intensity $I_0$ is incident on three polarizing filters. The axis of the first is vertical. That of the second is 45° from vertical, and that of the third is horizontal. What light intensity emerges from the third filter?