# Chapter 21: Electric Fields

## Practice Problems

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1. A negative charge of $2.0 \times 10^{-8}$ C experiences a force of 0.060 N to the right in an electric field. What is the field magnitude and direction?

$$E = \frac{F}{q'} = \frac{0.060\ \text{N}}{2.0 \times 10^{-8}\ \text{C}}$$

= $3.0 \times 10^2$ N/C to the left

2. A positive test charge of $5.0 \times 10^{-4}$ C is in an electric field that exerts a force of $2.5 \times 10^{-4}$ N on it. What is the magnitude of the electric field at the location of the test charge?

$$E = \frac{F}{q'} = \frac{2.5 \times 10^{-4}\ \text{N}}{5.0 \times 10^{-4}\ \text{C}} = 0.50\ \text{N/C}$$

3. Suppose the electric field in Practice Problem 2 were caused by a point charge. The test charge is moved to a distance twice as far from the charge. What is the magnitude of the force that the field exerts on the test charge now?

$$F_2/F_1 = (Kqq'/d_2^2)/(Kqq'/d_1^2) = (d_1/d_2)^2 \text{ with } d_2 = 2d_1$$

$$F_2 = (d_1/d_2)^2F_1 = (d_1/2d_1)^2(2.5 \times 10^{-4}\ \text{N}) = 6.3 \times 10^{-5}\ \text{N}$$

4. You are probing the field of a charge of unknown magnitude and sign. You first map the field with a $1.0 \times 10^{-6}$ C test charge, then repeat your work with a $2.0 \times 10^{-6}$ C charge.

   a. Would you measure the same forces with the two test charges? Explain.

   No. The force on the 2.0 $\mu$C charge would be twice that on the 1.0 $\mu$C charge.

   b. Would you find the same fields? Explain.

   Yes. You would divide the force by the strength of the test charge, so the results would be the same.

## Practice Problems

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5. The electric field intensity between two large, charged, parallel metal plates is 8000 N/C. The plates are 0.05 m apart. What is the potential difference between them?

$$V = Ed = (8000\ \text{N/C})(0.05\ \text{m}) = 400\ \text{J/C} = 4 \times 10^2\text{V}$$

6. A voltmeter reads 500 V when placed across two charged parallel plates. The plates are 0.020 m apart. What is the electric field between them?

$$V = Ed$$

$$E = \frac{V}{d} = \frac{500\ V}{0.020\ \text{m}} = 2.5 \times 10^4\ \text{N/C}$$

7. What potential difference is applied to two metal plates 0.500 m apart if the electric field between them is $2.50 \times 10^3$ N/C?

$$V = Ed = (2.50 \times 10^3\ \text{N/C})(0.500\ \text{m}) = 1.25 \times 10^3\ V$$

8. What work is done when 5.0 C is raised in potential by 1.5 V?

$$W = qV = (5.0\ \text{C})(1.5\ \text{V}) = 7.5\ \text{J}$$

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9. A drop is falling in a Millikan oil drop apparatus when the electric field is off.

   a. What are the forces on it, regardless of its acceleration?

   Gravitational force (weight) downward, frictional force of air upward.

   b. If it is falling at constant velocity, what can be said of the forces on it?

   The two are equal in magnitude.

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## Practice Problems

10. An oil drop weighs $1.9 \times 10^{-15}$ N. It is suspended in an electric field of $6.0 \times 10^{3}$ N/C.

**a.** What is the charge on the drop?

$F = Eq$

$$q = \frac{F}{E} = \frac{1.9 \times 10^{-15}\ \text{N}}{6.0 \times 10^{3}\ \text{N/C}} = 3.2 \times 10^{-19}\ \text{C}$$

**b.** How many excess electrons does it carry?

$$\#\ \text{electrons} = \frac{q}{q_e} = \frac{3.2 \times 10^{-19}\ \text{C}}{1.6 \times 10^{-19}\ \text{C/electron}}$$

$$= 2\ \text{electrons}$$

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11. A positively-charged oil drop weighs $6.4 \times 10^{-13}$ N. An electric field of $4.0 \times 10^{6}$ N/C suspends the drop.

**a.** What is the charge on the drop?

$F = Eq$

$$q = \frac{F}{E} = \frac{6.4 \times 10^{-13}\ \text{N}}{4.0 \times 10^{6}\ \text{N/C}} = 1.6 \times 10^{-19}\ \text{C}$$

**b.** How many electrons is the drop missing?

$$\#\ \text{electrons} = \frac{q}{1.6 \times 10^{-19}\ \text{C/electron}}$$

$$= 1\ \text{electron}$$

12. If three more electrons were removed from the drop in Practice Problem 11, what field would be needed to balance the drop?

$$E = \frac{F}{q} = \frac{6.4 \times 10^{-13}\ \text{N}}{(4)(1.6 \times 10^{-19}\ \text{C})} = 1.0 \times 10^{6}\ \text{N/C}$$

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13. 1 27-$\mu F$ capacitor has a potential difference of 25 V across it. What is the charge on the capacitor?

$q = CV = 27\ \mu F(25\ \text{V}) = 6.8 \times 10^{-4}$ C

## Practice Problems

14. Both a 3.3-$\mu F$ and a 6.8-$\mu F$ capacitor are connected across a 15-V potential difference. Which capacitor has a greater charge? What is it?

$q = CV$, so the larger capacitor has a greater charge.
$q = 1.0 \times 10^{-4}$ C

15. The same two capacitors are each charged to $2.5 \times 10^{-4}$ C. Across which is the potential difference larger? What is it?

$V = q/C$, so the smaller capacitor has the larger potential difference.
$V = (2.5 \times 10^{-4}\ \text{C})/(3.3 \times 10^{-6}\ \text{F}) = 76$ V

16. A 2.2-$\mu F$ capacitor is first charged so that the potential difference is 6.0 V. How much *additional* charge is needed to increase the potential difference to 15.0 V?

$q = CV$ so $\Delta q = C\Delta V$;
$\Delta q = (2.2\mu\text{F})(15.0\ \text{V} - 6.0\ \text{V}) = 2.0 \times 10^{-5}$ C

## Chapter Review Problems

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*The charge on an electron is* $-1.60 \times 10^{-19}$ C.

1. A positive charge of $1.0 \times 10^{-5}$ C experiences a force of 0.20 N when located at a certain point. What is the electric field intensity at that point?

$$E = \frac{F}{q} = \frac{0.20\ \text{N}}{1.0 \times 10^{-5}\ \text{C}} = 2.0 \times 10^{4}\ \text{N/C}$$

2. What charge exists on a test charge that experiences a force of $1.4 \times 10^{-8}$ N at a point where the electric field intensity is $2.0 \times 10^{-4}$ N/C?

$E = \frac{F}{q}$, so $Eq = F$, and

$$q = \frac{F}{E} = \frac{1.4 \times 10^{-8}\ \text{N}}{2.0 \times 10^{-4}\ \text{N/C}} = 7.0 \times 10^{-5}\ \text{C}$$

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## Chapter Review Problems

A test charge has a force of 0.20 N on it when it is placed in an electric field intensity of $4.5 \times 10^5$ N/C. What is the magnitude of the charge?

$E = \frac{F}{q}$, so

$q = \frac{F}{E} = \frac{0.20 \text{ N}}{4.5 \times 10^5 \text{ N/C}} = 4.4 \times 10^{-7}$ C

4. The electric field in the atmosphere is about 150 N/C (downward).

a. What is the direction of force on a positively-charged particle?

Downward.

b. Find the electric force on a proton with charge $+1.6 \times 10^{-19}$ C.

$E = \frac{F}{q}$, so

$F = qE = (1.6 \times 10^{-19} \text{ C})(150 \text{ N/C}) = 2.4 \times 10^{-17}$ N

c. Compare the force in **b** with the force of gravity on the same proton that has a mass of $1.7 \times 10^{-27}$ kg.

$F = mg = (1.7 \times 10^{-27} \text{ kg})(9.8 \text{ m/s}^2) = 1.7 \times 10^{-26}$ N (downward), more than one billion times smaller.

5. Electrons are accelerated by the electric field (Table 21–1) in a television picture tube.

a. Find the force on an electron.

$E = \frac{F}{q}$, so

$F = qE = (-1.6 \times 10^{-19} \text{ C})(10^5 \text{ N/C}) = -1.6 \times 10^{-14}$ N opposite the field.

b. If the field is constant, find the acceleration of the electron, mass $= 9.11 \times 10^{-31}$ kg.

$F = ma$, so

$a = \frac{F}{m} = \frac{-1.6 \times 10^{-14} \text{ N}}{9.11 \times 10^{-31} \text{ kg}} = -1.8 \times 10^{16} \text{ m/s}^2$

## Chapter Review Problems

6. A lead nucleus carries the charge of 82 protons.

a. What is the direction and magnitude of the electric field at $1.0 \times 10^{-10}$ m from the nucleus?

$Q = (82 \text{ protons})(1.6 \times 10^{-19} \text{ C/proton}) = 1.3 \times 10^{-17}$ C

$E = \frac{F}{q}$, so

$F = Eq$ and $F = \frac{KqQ}{d^2}$, so

$E = \frac{KQ}{d^2}$

$= \frac{(9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(1.3 \times 10^{-17} \text{ C})}{(10^{-10} \text{ m})^2}$

$= 1.2 \times 10^{13}$ N/C, outward

b. Use Coulomb's law to find the direction and magnitude of the force exerted on an electron located at this distance.

$F = Eq$
$= (1.2 \times 10^{13} \text{ N/C})(-1.6 \times 10^{-19} \text{ C})$
$= -1.9 \times 10^{-6}$ N, toward the nucleus

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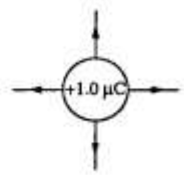
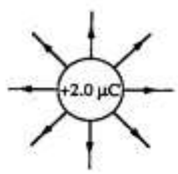
7. Carefully sketch

a. the electric field produced by a $+1.0\text{-}\mu$C charge.




b. the electric field due to a $+2.0\text{-}\mu$C charge. Make the number of field lines proportional to the change in charge.

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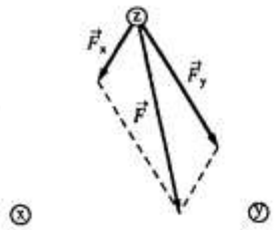
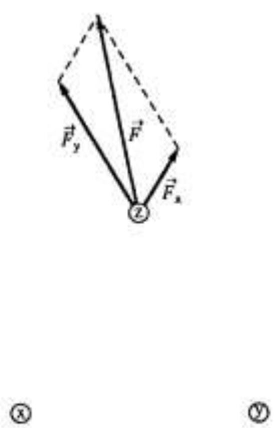
## Chapter Review Problems

8. Charges $x$, $y$ and $z$ are all equidistant from each other. $x$ has a $+1.0\text{–}\mu C$ charge, $y$ a $+2.0\text{–}\mu C$ charge, and $z$ a small negative charge.

   a. Draw an arrow showing the force on charge $z$.



   b. Charge $z$ now has a small positive charge on it. Draw an arrow showing the force on it.



9. A positive test charge of $8.0 \times 10^{-5}$ C is placed in an electric field of 50.0 N/C intensity. What is the strength of the force exerted on the test charge?

   $E = \frac{F}{q}$, so

   $F = Eq = (8.0 \times 10^{-5}\ \text{C})(50.0\ \text{N/C}) = 4.0 \times 10^{-3}\ \text{N}$

## Chapter Review Problems

10. If 120 J of work are done to move one coulomb of charge from a positive plate to a negative plate, what voltage difference exists between the plates?

    $V = \frac{w}{q} = \frac{120\ \text{J}}{1.0\ \text{C}} = 120\ \text{V}$

11. How much work is done to transfer 0.15 C of charge through a potential difference of 9.0 V?

    $V = \frac{w}{q}$, so

    $w = qV = (0.15\ \text{C})(9.0\ \text{V}) = 1.4\ \text{J}$

12. An electron is moved through a potential difference of 500 V. How much work is done on the electron?

    $V = \frac{w}{q}$, so

    $w = qV = (-1.60 \times 10^{-19}\ \text{C})(500\ \text{V}) = -8.00 \times 10^{-17}\ \text{J}$

13. A 12–V battery does 1200 J of work transferring charge. How much charge is transferred?

    $V = \frac{w}{q}$, so $W = qV$, and

    $q = \frac{W}{V} = \frac{1200\ \text{J}}{12\ \text{V}} = 1.0 \times 10^{2}\ \text{C}$

14. A force of 0.053 N is required to move a charge of 37 $\mu$C a distance of 25 cm in an electric field. What is the size of the potential difference between the two points?

    $W = F \cdot d$ and

    $V = \frac{W}{q} = \frac{F \cdot d}{q} = \frac{(0.053\ \text{N})(0.25\ \text{m})}{37 \times 10^{-6}\ \text{C}} = 3.6 \times 10^{2}\ \text{V}$

15. The electric field intensity between two charged plates is $1.5 \times 10^{3}$ N/C. The plates are 0.080 m apart. What is the potential difference, in volts, between the plates?

    $V = Ed = (1.5 \times 10^{3}\ \text{N/C})(0.080\ \text{m}) = 1.2 \times 10^{2}\ \text{V}$

## Chapter Review Problems

16. A voltmeter indicates that the difference in potential between two plates is 50.0 V. The plates are 0.020 m apart. What electric field intensity exists between them?

$V = Ed$, so

$$E = \frac{V}{d} = \frac{50.0\ \text{V}}{0.020\ \text{m}} = 2500\ V/m$$
$$= 2.5 \times 10^3\ \text{N/C}$$

17. A negatively-charged oil drop weighs $8.5 \times 10^{-15}$ N. The drop is suspended in an electric field intensity of $5.3 \times 10^3$ N/C.

a. What is the charge on the drop?

$$E = \frac{F}{q}, \text{ so}$$
$$q = \frac{F}{E} = \frac{8.5 \times 10^{-15}\ \text{N}}{5.3 \times 10^3\ \text{N/C}} = 1.6 \times 10^{-18}\ \text{C}$$

b. How many electrons does it carry?

$$\frac{1.6 \times 10^{-18}\ \text{C}}{1}\left[\frac{\text{electron}}{1.6 \times 10^{-19}\ \text{C}}\right] = 10\ \text{electrons}$$

18. In an early set of experiments, (1911), Millikan observed that the following measured charges, among others, appeared at different times on a single oil drop.

What value of elementary charge can be deduced from these data?

a. $6.563 \times 10^{-19}$ C

b. $8.204 \times 10^{-19}$ C

c. $11.50 \times 10^{-19}$ C

d. $13.13 \times 10^{-19}$ C

e. $16.48 \times 10^{-19}$ C

f. $18.08 \times 10^{-19}$ C

g. $19.71 \times 10^{-19}$ C

h. $22.89 \times 10^{-19}$ C

i. $26.13 \times 10^{-19}$ C

## Chapter Review Problems

$1.63 \times 10^{-19}$ C. Subtracting adjacent values, $b-a$, $c-d$, $d-c$, etc. yields $1.641 \times 10^{-19}$ C, $3.30 \times 10^{-19}$ C, $1.63 \times 10^{-19}$ C, $3.35 \times 10^{-19}$ C, $1.60 \times 10^{-19}$ C, $1.63 \times 10^{-19}$ C, $3.18 \times 10^{-19}$ C, $3.24 \times 10^{-19}$ C.
There are two numbers, approximately $1.63 \times 10^{-19}$ C and $3.2 \times 10^{-19}$ C, which are common. Averaging each similar group produces one charge of $1.63 \times 10^{-19}$ C and one charge of $3.27 \times 10^{-19}$ C (which is two times $1.63 \times 10^{-19}$ C).
Dividing $1.63 \times 10^{-19}$ C into each piece of data yields nearly whole number quotients indicating it is the value of an elementary charge.

19. A capacitor that is connected to a 45.0–V source contains 90.0 $\mu$C of charge. What is the capacitor's capacitance?

$$C = \frac{q}{V} = \frac{90.0 \times 10^{-6}\ \text{C}}{45.0\ \text{V}} = 2.00\ \mu F$$

20. A 5.4–$\mu F$ capacitor is charged with $2.7 \times 10^{-3}$ C. What potential difference exists across it?

$$C = \frac{q}{V}, \text{ so}$$
$$V = \frac{q}{C} = \frac{2.7 \times 10^{-3}\ \text{C}}{5.4 \times 10^{-6}\ \text{F}} = 5.0 \times 10^2\ \text{V}$$

21. What is the charge in a 15.0–pf capacitor when it is connected across a 75.0–V source?

$$C = \frac{q}{V}, \text{ so}$$
$$q = CV = (15.0 \times 10^{-12}\ \text{F})(75.0\ \text{V})$$
$$= 1.13 \times 10^{-9}\ \text{C}$$

22. The energy stored in a capacitor with capacitance $C$ having a potential difference $V$ is given by $W = \frac{1}{2}CV^2$. One application is in the electronic photoflash or strobe light. In such a unit, a capacitor of 10.0 $\mu$F is charged to $3.00 \times 10^2$ V. Find the energy stored.

$$W = \frac{1}{2}CV^2 = \frac{1}{2}(10.0 \times 10^{-6}\ \text{F})(3.00 \times 10^2\ \text{V})^2$$
$$= 0.450\ \text{J}$$

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# Chapter 23: Series and Parallel Circuits

## Practice Problems

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1. There are three 20–Ω resistors connected in series across a 120–V generator.

   a. What is the effective resistance of the circuit?

   $R = R_1 + R_2 + R_3$
   $= 20\ \Omega + 20\ \Omega + 20\ \Omega$
   $= 60\ \Omega$

   b. What is the current in the circuit?

   $I = V/R = (120\ \text{V})/(60\ \Omega) = 2.0\ \text{A}$

2. A 10–Ω resistor, a 15–Ω resistor, and a 5–Ω resistor are connected in series across a 90–V battery.

   a. What is the effective resistance of the circuit?

   $R = 10\ \Omega + 15\ \Omega + 5\ \Omega = 30\ \Omega$

   b. What is the current in the circuit?

   $I = V/R = (90\ \text{V})/(30\ \Omega) = 3.0\ \text{A}$

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3. Consider a 9–V battery in a circuit with three resistors connected in series.

   a. If the resistance of one of the devices increases, how will the series resistance change?

   It will increase.

   b. What will happen to the current?

   $I = V/R$, so it will decrease.

   c. Will there be any change in the battery voltage?

   No. It does not depend on the resistance.

## Practice Problems

4. Ten Christmas tree bulbs connected in series have equal resistances. When connected to 120–V outlet, the current through the bulbs is 0.06 A.

   a. What is the effective resistance of the circuit?

   $R = V/I = (120\ \text{V})/(0.06\ \text{A}) = 2000\ \Omega$

   b. What is the resistance of each bulb?

   $2000\ \Omega/10 = 200\ \Omega$

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5. A 20.0–Ω resistor and a 30.0–Ω resistor are connected in series and placed across a 120–V potential difference.

   a. What is the effective resistance of the circuit?

   $R = 20.0\ \Omega + 30.0\ \Omega = 50.0\ \Omega$

   b. What is the current in the circuit?

   $I = V/R = (120\ \text{V})/(50.0\ \Omega) = 2.40\ \text{A}$

   c. What is the voltage drop across each resistor?

   $V = IR$. Across 20.0 Ω–resistor,
   $V = (2.40\ \text{A})(20.0\ \Omega) = 48.0\ \text{V}$.
   Across 30.0 Ω–resistor,
   $V = (2.40\ \text{A})(30.0\ \Omega) = 72.0\ \text{V}$

   d. What is the voltage drop across the two resistors together?

   $V = 48.0\ \text{V} + 72.0\ \text{V} = 120\ \text{V}$

6. Three resistors of 3.0 kΩ ($3.0 \times 10^3\ \Omega$), 5.0 kΩ, and 4.0 kΩ are connected in series across a 12–V battery.

   a. What is the effective resistance?

   $R = 3.0\ \text{k}\Omega + 5.0\ \text{k}\Omega + 4.0\ \text{k}\Omega = 12.0\ \text{k}\Omega$

## Practice Problems

**b.** What is the current through the resistors?

$I = V/R = (12\ V)/(12.0\ k\Omega)$
$= 1.0\ mA = 1.0 \times 10^{-3}\ A$

**c.** What is the voltage drop across each resistor?

$V = IR$,
so $V = 3.0\ V$, $5.0\ V$, and $4.0\ V$

**d.** Find the total voltage drop across the three resistors.

$V = 3.0\ V + 5.0\ V + 4.0\ V$
$= 12.0\ V$

**7.** A student makes a voltage divider from a 45–V battery, a 475–kΩ ($475 \times 10^3\ \Omega$) resistor, and a 235–kΩ resistor. The output voltage is measured across the smaller resistor. What is the voltage?

$V_2 = VR_2/(R_1 + R_2)$
$= (45\ V)(235\ k\Omega)/(475\ k\Omega + 235\ k\Omega)$
$= 15\ V$

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**8.** A photoresistor is used in a voltage divider as $R_2$. $V = 9.0\ V$ and $R_1 = 500\ \Omega$.

**a.** What is the output voltage, $V_2$ across $R_2$, when a bright light strikes the photoresistor and $R_2 = 475\ \Omega$?

$V_2 = VR_2/(R_1 + R_2)$
$= (9.0\ V)(475\ \Omega)/(500\ \Omega + 475\ \Omega)$
$= 4.4\ V$

**b.** When the light is dim, $R_2 = 4.0\ k\Omega$. What is $V_2$?

$V_2 = VR_2/(R_1 + R_2)$
$= (9.0\ V)(4.0\ k\Omega)/(0.50\ k\Omega + 4.0\ k\Omega)$
$= 8.0\ V$

**c.** When the photoresistor is in total darkness, $R_2 = 0.40\ M\Omega$ ($0.40 \times 10^6\ \Omega$). What is $V_2$?

$V_2 = VR_2/(R_1 + R_2)$
$$= \frac{(9.0\ V)(4.0 \times 10^5\ \Omega)}{(0.005 \times 10^5\ \Omega + 4.0 \times 10^5\ \Omega)}$$
$= 9.0\ V$

## Practice Problems

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**9.** Three 15–Ω resistors are connected in parallel and placed across a 30–V potential difference.

**a.** What is the equivalent resistance of the parallel circuit?

$1/R = 1/R_1 + 1/R_2 + 1/R_3$
$= 3/15\ \Omega$, $R = 5.0\ \Omega$

**b.** What is the current through the entire circuit?

$I = V/R = (30\ V)/(5.0\ \Omega) = 6.0\ A$

**c.** What is the current through each branch of the parallel circuit?

$I = V/R = (30\ V)/(15.0\ \Omega) = 2.0\ A$

**10.** A 12.0–Ω resistor and a 15.0–Ω resistor are connected in parallel and placed across the terminals of a 15.0–V battery.

**a.** What is the equivalent resistance of the parallel circuit?

$1/R = 1/15.0\ \Omega + 1/12.0\ \Omega$, so
$R = 6.67\ \Omega$

**b.** What is the current through the entire circuit?

$I = V/R = (15.0\ V)/(6.67\ \Omega) = 2.25\ A$

**c.** What is the current through each branch of the parallel circuit?

$I = V/R = (15.0\ V)/(15.0\ \Omega)$
$= 1.00\ A$, $(15.0\ V)/(12.0\ \Omega)$
$= 1.25\ A$

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**11.** A 120.0–Ω resistor, a 60.0–Ω resistor, and a 40.0–Ω resistor are connected in parallel and placed across a potential difference of 12.0 V.

**a.** What is the equivalent resistance of the parallel circuit?

$1/R = 1/120.0\ \Omega + 1/60.0\ \Omega + 1/40.0\ \Omega$,
$R = 20.0\ \Omega$

## Practice Problems

b. What is the current through the entire circuit?

$I = V/R$
$= (12.0\text{ V})/(20.0\ \Omega)$
$= 0.600\text{ A}$

c. What is the current through each branch of the parallel circuit?

$I = V/R = (12.0\text{ V})/(120.0\ \Omega)$
$= 0.100\text{ A},\ (12.0\text{ V})/(60.0\ \Omega)$
$= 0.200\text{ A},\ (12.0\text{ V})/(40.0\ \Omega)$
$= 0.300\text{ A}$

12. Suppose the 12.0-Ω resistor in Practice Problem 10 is replaced by a 10.0-Ω resistor.

a. Does the equivalent resistance become smaller, larger, or remain the same?

Smaller.

b. Does the amount of current through the entire circuit change? in what way?

Gets larger.

c. Does the amount of current through the 15.0-Ω resistor change? in what way?

No. It remains the same. Currents are independent.

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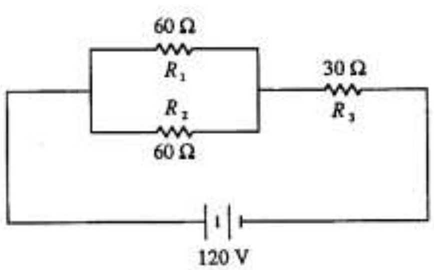
13. Two 60-Ω resistors are connected in parallel. This parallel arrangement is connected in series with a 30-Ω resistor. The combination is then placed across a 120-V potential difference.

a. Draw a diagram of the circuit.




## Practice Problems

b. What is the equivalent resistance of the parallel portion of the circuit?

$$\frac{1}{R} = \frac{1}{60\ \Omega} + \frac{1}{60\ \Omega} = \frac{2}{60\ \Omega}$$

$$R = \frac{60\ \Omega}{2} = 30\ \Omega$$

c. What single resistance could replace the three original resistors?

$R_{eff} = 30\ \Omega + 30\ \Omega = 60\ \Omega$

d. What is the current in the circuit?

$$I = \frac{V}{R} = \frac{120\text{ V}}{60\ \Omega} = 2.0\text{ A}$$

e. What is the voltage drop across the 30-Ω resistor?

$V_3 = IR_3 = (2.0)(30\ \Omega) = 60\text{ V}$

f. What is the voltage drop across the parallel portion of the circuit?

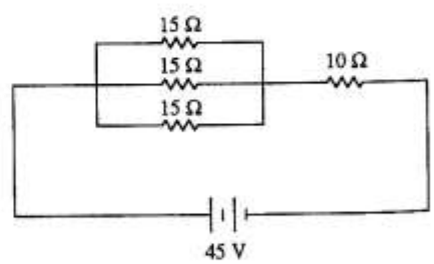
$V = IR = (2.0\text{ A})(30\ \Omega) = 60\text{ V}$

g. What is the current in each branch of the parallel portion of the circuit?

$$I = \frac{V}{R_1} = \frac{V}{R_2} = \frac{60\text{ V}}{60\ \Omega} = 1.0\text{ A}$$

14. Three 15-Ω resistors are connected in parallel. This arrangement is connected in series with a 10-Ω resistor. The entire combination is then placed across a 45-V difference in potential.

a. Draw a diagram of the circuit.



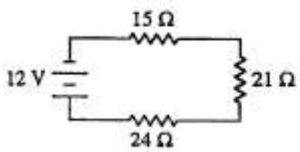
## Supplemental Problems (Appendix B)

c. Find the potential difference across the 125-Ω lamp.

$V = IR = (0.143\ \text{A})(125\ \Omega) = 17.9\ \text{V}$

2. The load across a 12-V battery consists of a series combination of three resistances that are 15 Ω, 21 Ω, and 24 Ω respectively.

a. Draw the circuit diagram.




b. What is the total resistance of the load?

$R_T = R_1 + R_2 + R_3 = 15\ \Omega + 21\ \Omega + 24\ \Omega = 60\ \Omega$

c. What is the magnitude of the circuit current?

$V = IR$, so $I = \frac{V}{R} = \frac{12\ \text{V}}{60\ \Omega} = 0.20\ \text{A}$

3. The load across a 12-V battery consists of a series combination of three resistances $R_1$, $R_2$, and $R_3$. $R_1$ is 210 Ω, $R_2$ is 350 Ω and $R_3$ is 120 Ω.

a. Find the equivalent resistance of the circuit.

$$R_T = R_1 + R_2 + R_3 = 210\ \Omega + 350\ \Omega + 120\ \Omega = 680\ \Omega$$

b. Find the current in the circuit.

$V = IR$, so

$I = \frac{V}{R} = \frac{12\ \text{V}}{680\ \Omega} = 1.8 \times 10^{-2}\ \text{A} = 18\ \text{mA}$

c. Find the potential difference across $R_3$.

$V = IR = (1.8 \times 10^{-2}\ \text{A})(120\ \Omega) = 2.2\ \text{V}$

## Supplemental Problems

4. The load across a 40-V battery consists of a series combination of three resistances, $R_1$, $R_2$, and $R_3$. $R_1$ is 240 Ω, and $R_3$ is 120 Ω. The potential difference across $R_1$ is 24 V.

a. Find the current in the circuit.

$V = IR$, so $I = \frac{V_1}{R_1} = \frac{24\ \text{V}}{240\ \Omega} = 0.10\ \text{A}$

b. Find the equivalent resistance of the circuit.

$V = IR$, so $R = \frac{V}{I} = \frac{40\ \text{V}}{0.10\ \text{A}} = 400\ \Omega$

c. Find the resistance of $R_2$.

$R_T = R_1 + R_2 + R_3$, so

$$R_2 = R_T - R_1 - R_3 = 400\ \Omega - 240\ \Omega - 120\ \Omega = 40\ \Omega$$

5. Pete is designing a voltage divider using a 12.0-V battery and a 100-Ω resistor as $R_2$. What resistor should be used as $R_1$ if the output voltage is 4.75 V?

$V_2 = \frac{VR_2}{R_1 + R_2}$, so $(R_1 + R_2)V_2 = VR_2$ and

$R_1V_2 = VR_2 - V_2R_2$, so

$$R_1 = \left[\frac{V - V_2}{V_2}\right]R_2 = \left[\frac{12.0 - 4.75}{4.75}\right]100\ \Omega = 153\ \Omega$$

6. Two resistances, one 12 Ω and the other 18 Ω, are connected in parallel. What is the equivalent resistance of the parallel combination?

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{12\ \Omega} + \frac{1}{18\ \Omega}$, so $R = 7.2\ \Omega$

7. Three resistances of 12 Ω each are connected in parallel. What is the equivalent resistance?

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{12\ \Omega} + \frac{1}{12\ \Omega} + \frac{1}{12\ \Omega} = \frac{3}{12\ \Omega} = \frac{1}{4.0\ \Omega},\ \text{so } R = 4.0\ \Omega$$

## Supplemental Problems

8. Two resistances, one 62 Ω and the other 88 Ω, are connected in parallel. The resistors are then connected to a 12 V battery.

   a. What is the equivalent resistance of the parallel combination?

   $$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{62\ \Omega} + \frac{1}{88\ \Omega},$$

   so $R = 36\ \Omega$

   b. What is the current through each resistor?

   $$V = IR, \text{ so } I = \frac{V}{R} = \frac{12\ \text{V}}{62\ \Omega} = 0.19\ \text{A}$$

   $$I = \frac{V}{R} = \frac{12\ \text{V}}{88\ \Omega} = 0.14\ \text{A}$$

9. A 35 Ω, 55 Ω and 85 Ω resistor are connected in parallel. The resistors are then connected to a 35 V battery.

   a. What is the equivalent resistance of the parallel combination?

   $$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{35\ \Omega} + \frac{1}{55\ \Omega} + \frac{1}{85\ \Omega}, \text{ so}$$

   $R = 17\ \Omega$

   b. What is the current through each resistor?

   $$V = IR, \text{ so } I_1 = \frac{V}{R_1} = \frac{35\ \text{V}}{35\ \Omega} = 1.0\ \text{A}$$

   $$I_2 = \frac{V}{R_2} = \frac{35\ \text{V}}{55\ \Omega} = 0.64\ \text{A}$$

   $$I_3 = \frac{V}{R_3} = \frac{35\ \text{V}}{85\ \Omega} = 0.41\ \text{A}$$

10. A 110 V household circuit that contains a 1800 W microwave, a 1000 W toaster, and a 800 W coffee maker is connected to a 20 A fuse. Will the fuse melt if the microwave and the coffee maker are both on?

    $P = IV$, so

    $$I = \frac{P}{V} = \frac{1800\ \text{W}}{110\ \text{V}} = 16.4\ \text{A} \quad \text{(microwave)}$$

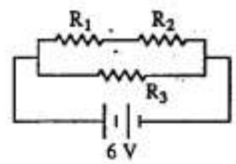
    $$I = \frac{P}{V} = \frac{800\ \text{W}}{110\ \text{V}} = 7.27\ \text{A} \quad \text{(coffee maker)}$$

    Total current of 23.7 A is greater than 20 A so the fuse will melt.

## Supplemental Problems

11. Resistors $R_1$, $R_2$, and $R_3$ have resistances of 15.0 Ω, 9.0 Ω, and 8.0 Ω respectively. $R_1$ and $R_2$ are connected in series and their combination is in parallel with $R_3$ to form a load across a 6.0 Volt battery.

    a. Draw the circuit diagram.

    b. What is the total resistance of the load?

    $R_1 + R_2 = 15.0\ \Omega + 9.0\ \Omega = 24.0\ \Omega$

    $$\frac{1}{R_T} = \frac{1}{R_{12}} + \frac{1}{R_3} = \frac{1}{24.0\ \Omega} + \frac{1}{8.0\ \Omega}, \text{ so}$$

    $R_T = 6.0\ \Omega$

    c. What is the magnitude of the circuit current?

    $$V = IR, \text{ so } I = \frac{V}{R} = \frac{6.0\ \text{V}}{6.0\ \Omega} = 1.0\ \text{A}$$

    d. What is the current in $R_3$?

    $$V = IR, \text{ so } I_3 = \frac{V}{R_3} = \frac{6.0\ \text{V}}{8.0\ \Omega} = 0.75\ \text{A}$$

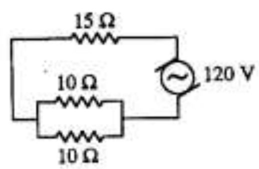
    e. What is the potential difference across $R_2$?

    $I_T = I_2 + I_3$, so
    $I_2 = I_T - I_3 = 1.0\ \text{A} - 0.75\ \text{A}$
    $= 0.25\ \text{A}$ and
    $V_2 = I_2R_2 = (0.25\ \text{A})(9.0\ \Omega) = 2.3\ \text{V}$

## Supplemental Problems

12. A 15.0 Ω resistor is connected in series to a 120 Volt generator and two 10.0 Ω resistors that are connected in parallel to each other.

**a.** Draw the circuit diagram.




**b.** What is the total resistance of the load?

$$\frac{1}{R_{12}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{10.0\ \Omega} + \frac{1}{10.0\ \Omega} = \frac{1}{5.0\ \Omega},$$

so $R_{12} = 5.0\ \Omega$

$R_T = R_3 + R_{12} = 15.0\ \Omega + 5.0\ \Omega = 20.0\ \Omega$

**c.** What is the magnitude of the circuit current?

$$V = IR, \text{ so } I = \frac{V}{R} = \frac{120\ \text{V}}{20.0\ \Omega} = 6.00\ \text{A}$$

**d.** What is the current in one of the 10.0 Ω resistors?

The current would divide equally, so 3.00 A.

**e.** What is the potential difference across 15.0 Ω resistor?

$V = IR = (6.00\ \text{A})(15.0\ \Omega) = 90.0\ \text{V}$

13. How would you change the resistance of a voltmeter to allow the voltmeter to measure a larger potential difference?

Increase the resistance.

14. How would you change the shunt in an ammeter to allow the ammeter to measure a larger current?

Decrease the resistance of the shunt.

## Supplemental Problems

15. An ohmmeter is made by connecting a 6.0 V battery in series with an adjustable resistor and an ideal ammeter. The ammeter deflects full-scale with a current of 1.0 mA. The two leads are touched together and the resistance is adjusted so 1.0 mA current flows.

**a.** What is the resistance of the adjustable resistor?

$V = IR$, so

$$R = \frac{V}{I} = \frac{6.0\ \text{V}}{1.0 \times 10^{-3}\ \text{A}} = 6.0 \times 10^3\ \Omega$$

**b.** The leads are now connected to an unknown resistance. What external resistance would produce a reading of 0.50 mA, half full-scale?

$$R = \frac{V}{I} = \frac{6.0\ \text{V}}{0.50 \times 10^{-3}\ \text{A}} = 1.2 \times 10^4\ \Omega \text{ and}$$

$R_T = R_1 + R_e$, so

$R_e = R_T - R_1 = 1.2 \times 10^4\ \Omega - 6.0 \times 10^3\ \Omega = 6 \times 10^3\ \Omega$

**c.** What external resistance would produce a reading of 0.25 mA, quarter-scale?

$$R = \frac{V}{I} = \frac{6.0\ \text{V}}{0.25 \times 10^{-3}\ \text{A}} = 2.4 \times 10^4\ \Omega \text{ and}$$

$R_e = R_T - R_1 = 2.4 \times 10^4\ \Omega - 6.0 \times 10^3\ \Omega = 1.8 \times 10^4\ \Omega$

**d.** What external resistance would produce a reading of 0.75 mA, three-quarter full-scale?

$$R = \frac{V}{I} = \frac{6.0\ \text{V}}{0.75 \times 10^{-3}\ \text{A}} = 8.0 \times 10^3\ \Omega \text{ and}$$

$R_e = R_T - R_1 = 8.0 \times 10^3\ \Omega - 6.0 \times 10^3\ \Omega = 2.0 \times 10^3\ \Omega$

# Chapter 22: Current Electricity

## Practice Problems

page 451

1. The current through a light bulb connected across the terminals of a 120–V outlet is 0.5 A. At what rate does the bulb convert electric energy to light?

   $P = VI = (120\ \text{V})(0.5\ \text{A}) = 60\ \text{J/s} = 60\ \text{W}$

2. A car battery causes a current of 2.0 A to flow through a lamp while 12 V is across it.. What is the power used by the lamp?

   $P = VI = (12\ \text{V})(2.0\ \text{A}) = 24\ \text{W}$

3. What current flows through a 75–W light bulb connected to a 120–V outlet?

   $P = VI,\ I = \frac{P}{V} = \frac{75\ \text{W}}{120\ \text{V}} = 0.63\ \text{A}$

4. The current through the starter motor of a car is 210 A. If the battery keeps 12 V across the motor, what electric energy is delivered to the starter in 10.0 s?

   $P = VI = (12\ \text{V})(210\ \text{A}) = 2500\ \text{W}$

   In 10 s, $E = Pt = (2500\ \text{J/s})(10\ \text{s})$

   $= 25000\ \text{J} = 2.5 \times 10^4\ \text{J}$

page 454

5. An automobile headlight with a resistance of 30 Ω is placed across a 12–V battery. What is the current through the circuit?

   $I = \frac{V}{R} = \frac{12\ \text{V}}{30\ \Omega} = 0.40\ \text{A}$

6. A motor with an operating resistance of 32 Ω is connected to a voltage source. The current in the circuit is 3.8 A. What is the voltage of the source?

   $V = IR = (3.8\ \text{A})(32\ \Omega) = 120\ \text{V}$

## Practice Problems

7. A transistor radio uses $2 \times 10^{-4}$ A of current when it is operated by a 3–V battery. What is the resistance of the radio circuit?

   $R = \frac{V}{I} = \frac{3\ \text{V}}{2 \times 10^{-4}\ \text{A}} = 1.5 \times 10^4\ \Omega$

   $= 2 \times 10^4\ \Omega$

8. A lamp draws a current of 0.5 A when it is connected to a 120–V source.

   a. What is the resistance of the lamp?

   $R = \frac{V}{I} = \frac{120\ \text{V}}{0.5\ \text{A}} = 240\ \Omega = 200\ \Omega$

   b. What is the power consumption of the lamp?

   $P = VI = (120\ \text{V})(0.5\ \text{A}) = 60\ \text{W}$

9. A 75–W lamp is connected to 120 V.

   a. How much current flows through the lamp?

   $I = P/V = (75\ \text{W})(120\ \text{V}) = 0.63\ \text{A}$

   b. What is the resistance of the lamp?

   $R = V/I = 120\ \text{V}/0.63\ \text{A} = 190\ \Omega$

10. A resistor is now added in series with the lamp to reduce the current to half of its original value.

    a. What is the potential difference across the lamp? Assume the lamp resistance is constant.

    The new value of the current is

    $0.63\ \text{A}/2 = 0.315\ \text{A}$, so

    $V = IR = (0.315\ \text{A})(190\ \Omega) = 60\ \text{V}$

## Practice Problems

**b.** How much resistance was added to the circuit?

The total resistance of the circuit is now $R_{total} = V/I = (120\ V)/(0.315\ A) = 380\ \Omega$.
Therefore, $R_{res} = R_{total} - R_{Lamp}$
$= 380\ \Omega - 190\ \Omega = 190\ \Omega$.

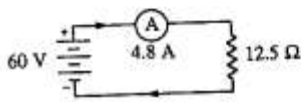
**c.** How much power is now dissipated in the lamp?

$P = VI = (60\ V)(0.315\ A) = 19\ W$

**page 457**

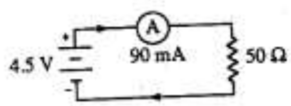
**11.** Draw a circuit diagram to include a 60-V battery, an ammeter, and a resistance of 12.5 Ω in series. Indicate the ammeter reading and the direction of current flow.

$$I = \frac{V}{R} = \frac{60\ V}{12.5\ \Omega} = 4.8\ A$$




**12.** Draw a series circuit diagram showing a 4.5-V battery, a resistor, and an ammeter reading 90 mA. Label the size of the resistor. Choose a direction for the conventional current and indicate the positive terminal of the battery.

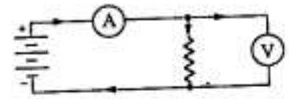
$R = V/I = (4.5\ V)(0.090\ A) = 50\ \Omega$




## Practice Problems

**13.** Add a voltmeter that measures the potential difference across the resistors in each of the Practice Problems above.

Both circuits will take the form




Since the ammeter resistance is assumed zero the voltmeter readings will be

practice problem 11 60 V
practice problem 12 4.5 V.

**page 459**

**14.** A 15-Ω electric heater operates on a 120-V outlet.

**a.** What is the current through the heater?

$I = V/R = (120\ V)(15\ \Omega) = 8.0\ A$

**b.** How much energy is used by the heater in 30.0 s?

$E = I^2Rt = (8.0\ A)^2(15\ \Omega)(30.0\ s)$
$= 2.9 \times 10^4\ J$

**c.** How much thermal energy is liberated by the heater in this time?

$2.9 \times 10^4$ J since all electrical energy is converted to thermal energy

**15.** A 30-Ω resistor is connected to a 60-V battery.

**a.** What is the current in the circuit?

$I = V/R = (60\ V)/(30\ \Omega) = 2.0\ A$

**b.** How much energy is used by the resistor in 5 min?

$E = I^2Rt = (2.0\ A)^2(30\ \Omega)(5\ min)(60\ s/min)$
$= 3.6 \times 10^4\ J$

# Chapter 24: Magnetic Fields

## Practice Problems

page 496

1. A student holds a bar magnet in each hand. If both hands are brought close together, will the force be attractive or repulsive if the magnets are held so that

   a. the two N–poles are brought close together?

      repulsive

   b. an N–pole and an S–pole are brought together?

      attractive

2. Figure 24–7 shows five disk magnets floating above each other. The N–pole of the top–most disk faces up. Which poles are on the top side of the other magnets?

   south, north, south, north

3. In the Chapter 1 opening photo, page 2, assume the N–pole is the bottom face of the floating magnet. Which is the direction of the induced field in the superconducting disk?

   The top face of the disk is the N–pole, so the direction of the field is up out of the N–pole.

4. Figure 24–3 shows a magnet attracting a nail to it which, in turn, has attracted many small tacks to it. If the N–pole of the permanent magnet is the top face, which end of the nail is the N–pole?

   The bottom (the point).

page 499

5. A long, straight, current–carrying wire runs from north to south.

   a. A compass needle placed above the wire points with its N–pole toward the east. In what direction is the current flowing?

      from south to north

Since N pole is east, the compass N is repelled and points in the opposite direction.

   b. If a compass is put underneath the wire, in which direction will the needle point?

      west

6. Suppose you measure the strength of the magnetic field 1 cm from a current carrying–wire.

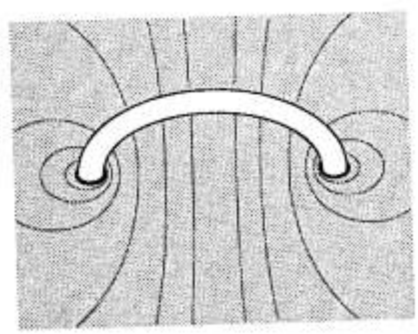
   a. Compare the strength 2 cm away to the strength of the field at 1 cm.

      Since magnetic field strength varies inversely with the distance from the wire, it will be half as strong.

   b. Now compare the strength of the field 3 cm from the wire.

      It is one–third as strong.

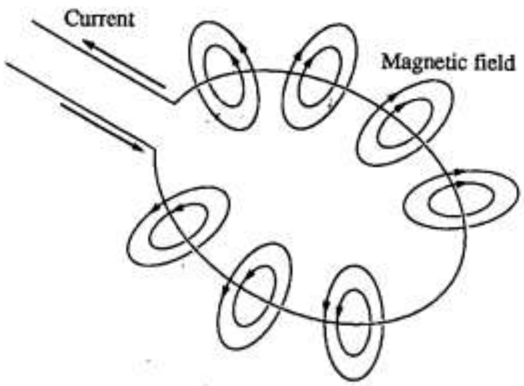
7. The loop in figure 24–11b has current running in a clockwise direction (from left to right above the cardboard). If a compass is placed on the cardboard beneath the loop, in which direction will the N–pole point?



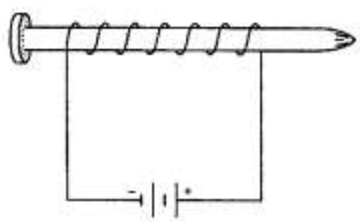
It will point toward the top of the page.

Chapter 24 Magnetic Fields 251

## Practice Problems




8. A student makes a magnet by winding wire around a large nail as in Figure 24–14. The magnet is connected to the battery as shown. Which end of the nail, pointed end or head, will be the N-pole?



Right Hand Rule – fingers follow magnetic field ("out" of page at top of nail) so thumb points right which is N – "pointed" end of nail

9. A straight wire 0.10 m long carrying a current of 2.0 A is at right angles to a magnetic field. The force on the wire is 0.04 N. What is the strength of the magnetic field?

$F = BIL,$

$$B = \frac{F}{IL} = \frac{0.04\ \text{N}}{(2.0\ \text{A})(0.10\ \text{m})} = 0.2\ \text{T}$$

10. A wire 0.50 m long carrying a current of 8.0 A is at right angles to a 0.40 T magnetic field. How strong a force acts on the wire?

$$F = BIL = (0.40\ \text{N/A}\cdot\text{m})(8.0\ \text{A})(0.50\ \text{m}) = 1.6\ \text{N}$$

## Practice Problems

**page 505**

11. A wire 75 cm long carrying a current of 6.0 A is at right angles to a uniform magnetic field. The magnitude of the force acting on the wire is 0.60 N. What is the strength of the magnetic field?

$$B = \frac{F}{IL} = \frac{0.60\ \text{N}}{(6.0\ \text{A})(0.75\ \text{m})} = 0.13\ \text{T}$$

12. A copper wire 40 cm long carries a current of 6.0 A and weighs 0.35 N. A certain magnetic field is strong enough to balance the force of gravity on the wire. What is the strength of the magnetic field?

$F = BIL$, $F$ = weight of wire.

$$B = \frac{F}{IL} = \frac{0.35\ \text{N}}{(6.0\ \text{A})(0.40\ \text{m})} = 0.15\ \text{T}$$

**page 508**

13. An electron passes through a magnetic field at right angles to the field at a velocity of $4.0 \times 10^6$ m/s. The strength of the magnetic field is 0.50 T. What is the magnitude of the force acting on the electron?

$$F = Bqv = (0.50\ \text{T})(1.6 \times 10^{-19}\ \text{C})(4.0 \times 10^6\ \text{m/s}) = 3.2 \times 10^{-13}\ \text{N}$$

**page 509**

14. A stream of doubly–ionized particles (missing two electrons and thus carrying a net charge of two elementary charges) moves at a velocity of $3.0 \times 10^4$ m/s perpendicular to a magnetic field of $9.0 \times 10^{-2}$ T. What is the magnitude of the force acting on each ion?

$$F = Bqv = (9.0\times10^{-2}\ \text{T})(2)(1.6\times10^{-19}\ \text{C})(3.0\times10^4\ \text{m/s}) = 8.6 \times 10^{-16}\ \text{N}$$

15. Triply–ionized particles in a beam carry a net positive charge of three elementary charge units. The beam enters a $4.0 \times 10^{-2}$–T magnetic field. The particles have a velocity of $9.0 \times 10^6$ m/s. What is the magnitude of the force acting on each particle?

$$F = Bqv$$
$$E = (4.0 \times 10^{-2}\text{T})(3)(1.6 \times 10^{-19}\text{C})(9.0\times 10^6\text{m/s}) = 1.7 \times 10^{-13}\ \text{N}$$