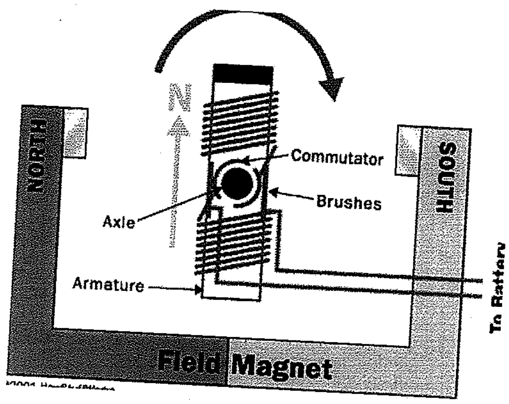
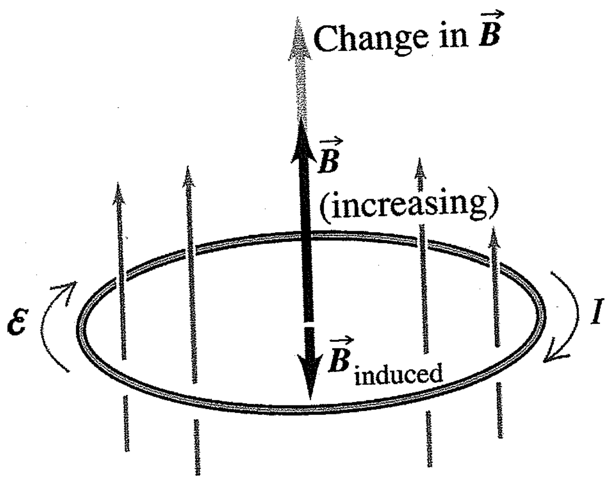
Electromagnetism
Unit 8



Magnetism

Electricity & Magnetism
Magnetic force on moving charge



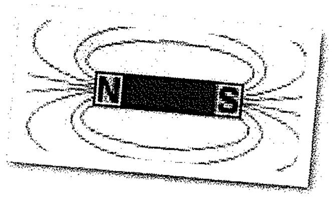
Ampere's Law
Solenoids/CRT's

Electromagnetic Induction - Faraday

Motional EMF

Induction in a moving conductor

Lenz's Law



Electric Generators

Electric Motors

Back or Counter EMF

Power Transmission

Lenz

Faraday

Name: ____________

EM Source and Field Practice Questions

EM and the Source of Magnetic Fields

1. A positive charge of 0.25 C moves horizontal at a speed of 2.0×10^2 m/s and enters a magnetic field of 0.01 T directed vertically downward. What is the force on the charge? (0.5 N)

2. A long, straight wire carries a current of 2.0 A. Find the magnitude of the magnetic field 50-cm from the wire. (8×10^{-7} T)

3. A horizontal beam of electrons travels at a speed of 10^3 m/s along a north-south line in a discharge tube. What is the force on the electron due to the vertical components of the Earth's magnetic field if it has a magnitude of 5.0×10^{-5} T at that location? (8×10^{-21} N (L))

4. An electron travelling at a uniform speed of 100 m/s in the $+x$ direction enters a uniform magnetic field and experiences a force of 4.00×10^{-15} N in the $+y$ direction. What is the magnitude and direction of the magnetic field? (2.5×10^2 T (Z))

5. A particle with a charge of 4.0×10^{-8} C moves at a speed of 2.0×10^2 m/s through a magnetic field in the direction at which the magnetic force on the particle is maximum. If the force on the particle is 1.8×10^{-6} N, what is the magnitude of the magnetic field? (0.23 T)

6. An electron travels at a speed of 2.0×10^4 m/s through a uniform magnetic field whose magnitude is 1000 T. What is the magnitude of the force on the electron if its velocity and the magnetic field vector (a) are perpendicular (b) make an angle of 45° or (c) are parallel? (3.2×10^{-12} N, 2.3×10^{-12} N, 0)

7. What current in along straight wire will produce a magnetic field with a magnitude of 4.0 μT at a perpendicular distance of 20 cm from the wire? (4 A)

8. A solenoid 50.0-cm long with 2000 turns/m has a central magnetic field of 0.60 mT. Find the current in the coil. (0.24 A)

9. A horizontal power line carries a current of 2500 A from West to East. What is the magnetic field 8.0-m below the line? (6.3×10^{-5} T)

10. Two long parallel wires separated by 50 cm carry currents of 10 A each in the horizontal direction. Find the magnetic field midway between the wires if the currents are (a) in the same direction and (b) in opposite directions. (0, 1.6×10^{-5} T)

11. A long, straight wire has a resistance of 2.0 Ω. What potential difference between the ends of the wire will produce a magnetic field of 10^{-4} T at a distance of 6.0 cm from the wire? (60 V)

12. Two long, parallel wires separated by 20 cm carry equal currents of 1.5 A in the same direction. Find the magnetic fields 10-cm away from either side of each wire on a line running perpendicular through both wires. (0T, 4.0×10^{-6} T)

13. A solenoid 10-cm long is wound with 3000 turns of wire. How much current must flow through the windings to produce a magnetic field of 3.0×10^{-3} T at the solenoid central axis? (0.08 A)

14. A proton moves at a speed of 1.0×10^4 m/s perpendicular to a uniform magnetic field of 80 mT. Find the radius of the resulting circular path. (1.3×10^{-3} m)

15. An electron has a kinetic energy of 20 keV. It enters a uniform magnetic field of 40 T that is perpendicular to its line of motion. What is the radius of the resulting circular path? (1.2×10^{-5} m)

16. A proton travels in a circular path of radius 60-mm in a uniform magnetic field of 12 μT. What is the kinetic energy of the proton? (3.97×10^{-24} J)

17. A solenoid is wound with 200 turns/cm. An outer layer of insulated wire with 180 turns/cm is wound over the first layer of wire. In operation, the inner coil carries a current of 5.0 A, and the outer coil carries a current of 7.5 A in the direction opposite to that of the current in the inner coil. What is the magnetic filed at the central axis of the doubly wound coil? (0.044 T)

18. A proton is accelerated from rest through a potential difference of 1.0 kV. It enters a uniform magnetic field of 5.0 mT that is perpendicular to the direction of its motion. (a) Find the radius of the circular path of the proton. (b) Calculate the period of revolution of the proton. (0.92 m, 1.3×10^{-5} s)

Magnetic Forces on Current-Carrying Wires

19. A straight, horizontal segment of wire is 1.0 m long and carries a current of 5.0 A in the $+x$ direction in a magnetic field of 0.60 T that is directed vertically upward. What is the force on the? (3 N)

20. A 2.0 m length of straight wire carries a current of 20 A in a uniform magnetic field of 50 mT whose field lines make an angle of 40° with the direction of the conventional current. Find the force on the wire. (1.3 N)

21. A straight wire, 50-cm long conducts a current of 10 A directed vertically upwards. If the wire experiences a force of 2.0×10^{-2} N in the eastward direction due to a magnetic field at right angles to its length, what is the magnitude and direction of the magnetic field? (4.3×10^{-3} T South)

22. A horizontal magnetic field of 10^{-2} T is at an angle of 30° to the direction of the current in a straight, horizontal wire 60-cm long. If the wire carries a current of 20 A, what is the magnitude of the force on the wire? (0.06 N)

23. How much current is flowing in a straight wire 4.0 m long if the force on it is 0.040 N when it placed in a perpendicular magnetic field of 0.50 T? (0.02 A)

24. Two long straight, parallel wires 10 cm apart carry equal currents of 3.0 A in opposite directions. What is the force per unit length on the wires? (1.8×10^{-5} N/m)

25. Two parallel wires are 4.0 long and 50 cm apart and carry equal currents of 2.5 A in opposite directions. (a) Find the force on each wire. (b) Find the force on each wire if their currents are in the same direction. (1.0×10^{-5} N repulsive, attractive)

26. A set of jumper cable used to start one car from another's battery is connected to the terminal of the car's batteries. If 15 A of current flows in the cables when the one car is started and the cables are parallel and 15 cm apart, what is the force per unit length on the cables? (3×10^{-4} N/m)

Applications of Electromagnetism

27. A beam of protons travelling at a speed of 2.0×10^{2} m/s passes through the space between two horizontal parallel plates, where a constant electric field and constant magnetic field are right angles to one another. If the electric field has a magnitude of 100 V/m and is directed from the bottom to the top plate, what must the magnitude and direction of the magnitude field be to allow the beam to pass undeflected? (Hint make a sketch of the situation)(0.5 T)

28. A charged particle travels undeflected through crossed electric and magnetic fields whose magnitudes are 6000 N/C and 300 mT respectively. Find the speed of the particle if it is (a) a proton or (b) an alpha particle. (2.0×10^{4} m/s, 2.0×10^{4} m/s)

29. An alpha particle is accelerated in the $+x$ direction through a potential of 1000 V. The particle then moves in an undeflected path between two oppositely charge parallel plates in a uniform magnetic field of 50 mT in the $+y$ direction. (a) If the plates are horizontal in the xy plane what is the magnitude of the electric field between them? (b) If the distance between the plates is 10 cm, what is the potential difference between them? (c) Which plate (top or bottom) is positively charged? Take the mass of an alpha particle to be 6.64×10^{-27} kg (1.55×10^{4} N/C, 1550 V, top = +)

30. In a mass spectrometer, double charge ion having a particular velocity is selected using a magnetic field of 100 mT perpendicular to an electric field of 1.0 kV/m. The same magnetic field is used to deflect the ion in a circular path with a radius of 15 mm. Find (a) the mass of the ion and (b) the kinetic energy of the ion. (c) Does the kinetic energy of the ion increase in the circular path? (4.8×10^{-26} kg, 2.4×10^{-18} J, No)

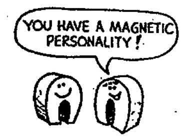
Name ____________ Period ______ Date ______

Concept-Development Practice Page 36-1

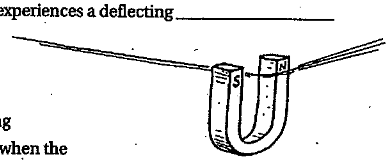
Magnetism

Fill in each blank with the appropriate word.

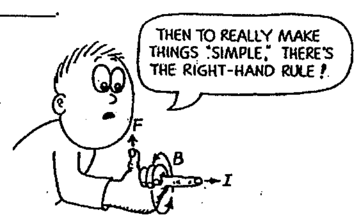
1. Attraction or repulsion of charges depends on their *signs*, positives or negatives. Attraction or repulsion of magnets depends on their magnetic ____________: ____________ or ____________.



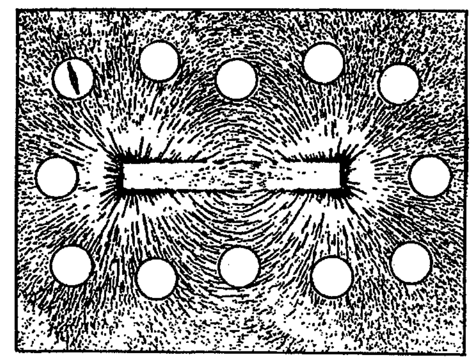
2. Opposite poles attract; like poles ____________.
3. A magnetic field is produced by the ____________ of electric charge.
4. Clusters of magnetically aligned atoms are magnetic ____________.
5. A magnetic ____________ surrounds a current-carrying wire.
6. When a current-carrying wire is made to form a coil around a piece of iron, the result is an ____________________.
7. A charged particle moving in a magnetic field experiences a deflecting ____________ that is maximum when the charge moves ____________ to the field.



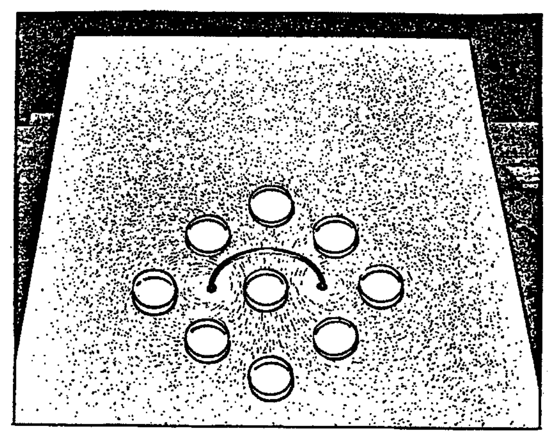
8. A current-carrying wire experiences a deflecting ____________ that is maximum when the wire and magnetic field are ____________ to one another.
9. A simple instrument designed to detect electric current is the ____________; when calibrated to measure current, it is an ____________; when calibrated to measure voltage, it is a ____________.
10. The largest size magnet in the world is the ____________ itself.



11. The illustration below is similar to Figure 36.4 in your textbook. Iron filings trace out patterns of magnetic field lines about a bar magnet. In the field are some magnetic compasses. The compass needle in only one compass is shown. Draw in the needles with proper orientation in the other compasses.



12. The illustration below is similar to Figure 36.13 (center) in your textbook. Iron filings trace out the magnetic field pattern about the loop of current-carrying wire. Draw in the compass needle orientations for all the compasses.



Physics 12

Magnetism Problems

1. A 0.500 m long wire of mass 1.00 g lies on a horizontal platform in a region of uniform magnetic field of 1.00×10^{-3} T. The field is perpendicular to the wire so that an upward force is exerted on the wire when a current passes through it. What is the minimum current required to lift the wire against its weight? (20 A)

2. A magnet with a field of 0.200 T over an effective area 10.0 cm in diameter exerts a force on a current carrying wire that crosses between the pole faces at right angles to the field. What is the force on the wire if the current is 10.0 A? (0.20 N)

3. An electric trolley car cable carries a direct current of 400 A in a region where the vertical component of the earth's magnetic field is 5.00×10^{-6} T. What is the horizontal force on a 10.0 m section of wire due to the magnetic field? (0.020 N)

4. A wire 0.250 m long carries a current of 0.750 A in a region of uniform magnetic field. The wire is subject to a force of 2.50 N when held perpendicular to the direction of the field. What is the magnitude of the magnetic field? (13.3 T)

5. A wire 0.500 m long carries a current of 6.00 A, and makes an angle of 45.0° with a uniform magnetic field. If the force on the wire is 0.106 N, what is the magnitude of the magnetic field? (0.050 T)

6. A horizontal wire 30.0 cm long makes an angle of 45.0° with a 0.0500 T magnetic field horizontally directed north. What are the magnitude and direction of the force on the wire when it carries a current of 1.00 A in the direction from southwest to northeast? (0.0106 N, up)

7. A proton is projected into a 0.140 T magnetic field. What is the acceleration of the proton if it is traveling perpendicular to the field at a speed of 1.05×10^{6} m/s? (1.41×10^{13} m/s^2)

8. Alpha particles from a radioactive source have a speed of 1.85×10^{7} m/s. How large a magnetic field is required to bend the path of the particles into a circle of 0.580 m radius? An alpha particle has a mass of 6.64×10^{-27} kg and a charge of 3.20×10^{-19} C. (0.662 T)

9. A proton is introduced into a field of 1.05 T with a velocity of 1.20×10^{6} m/s perpendicular to the field. What is the radius of the proton's path? (1.19 cm)

10. Suppose the initial velocity of the proton in question 9 makes an angle of 45.0° with the field. What is the subsequent motion of the proton? (helical, r=0.843 cm)

11. A particle having a 3.20×10^{-19} C electric charge is injected into a 0.100 T magnetic field with a speed of 3.00×10^{6} m/s. a) If the velocity of the particle is perpendicular to the field, what is the force on the particle? b) How great an electric field would be required to exert a force of the same magnitude on the particle? (9.6×10^{-14} N, 3.0×10^{5} N/C)

12. A charged particle moving through a bubble chamber travels in a circular arc of radius 0.530 m. If the 0.100 T magnetic field is perpendicular to the arc, what is the momentum of the particle? Assume the particle has the charge of an electron. (8.5×10^{-21} kgm/s)

13. A proton moving at right angles to a 0.100 T magnetic field travels in a circular orbit of radius 5.00 cm. What is the a) speed and, b) kinetic energy of the proton? (4.79×10^{5} m/s, 1.92×10^{-16} J)

14. A particle moves in a 0.270 m radius circular arc perpendicular to a 2.70×10^{-2} T field. The particle's kinetic energy is 4.10×10^{-16} J. The particle has a charge equal to the elementary charge. Is the particle an electron, proton or pion (mass 2.5×10^{-28} kg)? (proton)

15. A cyclotron operates in a 1.50 T magnetic field. If it is used to accelerate deutrons (mass 3.34×10^{-27} kg, charge 1.60×10^{-19} C), what must be the frequency of the oscillation of the accelerating voltage? (11.4 MHz)

16. A cyclotron used to accelerate deutrons is operated at 9.16 MHz. What is the magnetic field? (1.20 T)

17. What is the frequency of an electron in a region of a 1.00 T magnetic field? (28 GHz)

18. At what radius must deutrons be extracted from a cyclotron with a 1.00 T magnetic field if they are to have an energy of 2.00×10^{-12} J each? (0.722 m)

19. A long straight wire carries a current of 100 mA. What is the magnitude of the magnetic field 10.0 cm from the wire? (2.00×10^{-7} T)

20. A long straight wire carries a current of 50.0 A. At what distance from the wire will the magnetic field become equal to 5.00×10^{-5} T? (20 cm)

21. Two parallel wires spaced 0.500 m apart in a horizontal plane carry oppositely directed currents of 200 A. What is the force per unit length on the wires? Are the wires attracted or repelled? (0.016 N/m, repel)

22. Two parallel wires spaced a distance *d* apart experience an attractive force per unit length of 6.00×10^{-4} N/m. If the currents have a magnitude of 10.0 A each, what is the distance *d*? (3.33 cm)

23. Two parallel wires repel each other with a force per length of 1.00×10^{-3} N/m when spaced a distance of 2.50 cm apart. If one wire has a current of 100 A, what is the current in the other wire? (1.25A)

24. A solenoid 0.435 m long has 900 turns of wire. What is the magnetic field in the centre of the solenoid when it carries a current of 2.75 A? (7.15 mT)

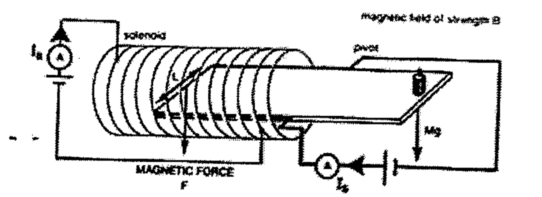
25. A 0.530 m long solenoid consisting of 1000 turns is used to generate a magnetic field of 0.150 T. How much current is required? (63 A)

26. A large solenoid is used to produce a field of 0.800 T. The 2.00 m long solenoid has 320 turns. How much current is required? (4000 A)

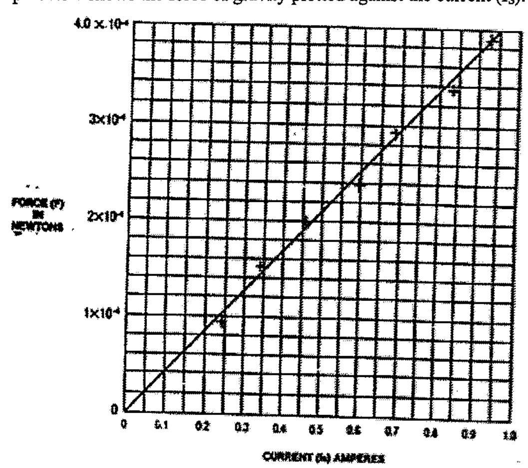
27. A charged particle is observed to move in a circle of 0.0823 m radius in a plane perpendicular to a uniform magnetic field of 7.69×10^{-3} T. The momentum of the particle is 2.03×10^{-22} kgm/s. What is the electric charge on the particle? (3.2×10^{-19} C)

28. An experiment requires protons with speeds of 2.00×10^{6} m/s perpendicular to a magnetic field to be deflected into a circular path of radius 2.00 m. The solenoid producing the field is supplied with a current of 1000 A. How many turns per meter should the solenoid have? (8.31 turns/m)

Current Balance Assignment Worksheet 4



The above diagram shows a current balance apparatus. The current through the solenoid (I_B) is a constant 3.00 A and the length of the current strip (L) is 2.50 cm. Masses are placed on the end of the balance, and the current through the strip (I_S) is varied so that the electromagnetic force on the current strip balances the force of gravity on the mass. The graph below shows the force of gravity plotted against the current (I_S).



Questions:
1. Calculate the slope of the line.
2. Find the *physical* or *experimental* relationship between the force and the current (i.e. the equation of the line)
3. Given that the *theoretical* relationship between magnetic force on a wire and the current through it is **F=BIl,** compare your experimental relationship with the theoretical relationship and use the given value of the length of the wire to calculate the magnitude of the field inside the solenoid.

Current Balance Practice Problems

1. a) An air-cored solenoid has 500 turns/cm of wire wound on a cylinder. What is the strength of the magnetic field (B) produced near the centre of the solenoid if the current through the windings is 3.00 A?
   b) What force would act on a wire placed along the central axis of the solenoid if the current through it was 4.00 A?
   c) What force would act on a wire of length 6.00 cm carrying 1.50 A placed perpendicular to the field inside the solenoid?
2. The field strength inside a solenoid is 0.0300 T. The length of a conducting strip at right angles to the magnetic field is 4.20 cm. How much current is there in the strip if it requires a 60.0 mg mass to balance the magnetic force on the strip?
3. In a current balance there is the same current, I, through both the solenoid and the strip. If a current of 1.50 A "balances" a mass of 0.100 g, what current would "balance" a mass of 0.300 g? (hint: find the relationship between F and I to solve the problem)

Deflecting Charges in Fields Practice Problems

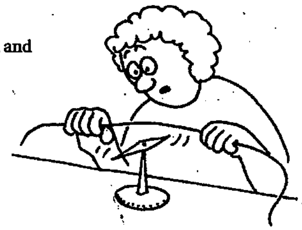
1. a) A magnetic field of magnitude 3.40 x 10^{-3} T deflects electrons into a circular path of radius 1.40 cm. The electrons have been accelerated through a potential difference of 250 V. If the charge of an electron is 1.60 x 10^{-19} C, what is the mass of an electron?
   b) If protons were accelerated by the same potential as the electrons in part a) and deflected by the same field, what would be the radius of their orbit?
   c) If the electrons were found to revolve clockwise in their circular orbits, explain why the protons would revolve counter-clockwise.
2. In a proton storage ring, very fast protons are kept in a circular orbit by a uniform magnetic field applied at right angles to the plane of the orbit.
   a) Show that the proton's period of revolution T is $2\pi m/qB$.
   b) Calculate the period of revolution, if the magnetic field strength is 1.20 x 10^{-2} T.
   c) If the protons have been accelerated through a potential difference of 3.00 x 10^{6} V, what strength of magnetic field is needed to keep them in an orbit of diameter 8.00 cm?
   d) How does your answer to c) compare with the value of the Earth's magnetic field near the surface (approx. 3.00 x 10^{-5} T)?
3. An instrument called a velocity selector has charged particles passing through a region where there is a uniform electric field 'E' perpendicular to a uniform magnetic field 'B'. The particles travel at right angles to both 'B' and 'E' so that the electric force and the magnetic force on them are in opposite directions. If 'B' is 0.350 T and 'E' is 6.00 x 10^{4} V/m, at what speed would particles pass through undeflected?

Worksheet 5

Name Period Date

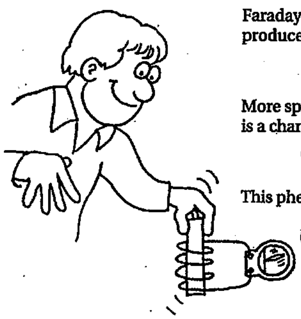
Concept-Development Practice Page 37-1

Faraday's Law



1. Hans Christian Oersted discovered that magnetism and electricity are
   (related) (independent of each other).

   Magnetism is produced by
   (batteries) (the motion of electric charges).



Faraday and Henry discovered that electric current can be produced by
(batteries) (motion of a magnet).

More specifically, voltage is induced in a loop of wire if there is a change in the
(batteries) (magnetic field in the loop).

This phenomenon is called
(electromagnetism) (electromagnetic induction).

2. When a magnet is plunged in and out of a coil of wire, voltage is induced in the coil. If the rate of the in-and-out motion of the magnet is doubled, the induced voltage
   (doubles) (halves) (remains the same).

   If instead the number of loops in the coil is doubled, the induced voltage
   (doubles) (halves) (remains the same).

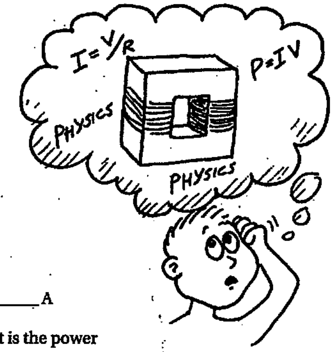
3. A rapidly changing magnetic field in any region of space induces a rapidly changing
   (electric field) (magnetic field) (gravitational field)

   which in turn induces a rapidly changing
   (magnetic field) (electric field) (baseball field).

   This generation and regeneration of electric and magnetic fields makes up
   (electromagnetic waves) (sound waves) (both of these).

Conceptual PHYSICS

Transformers



Consider a simple transformer that has a 100-turn primary coil and a 1000-turn secondary coil. The primary is connected to a 120-V AC source and the secondary is connected to an electrical device with a resistance of 1000 ohms.

1. What will be the voltage output of the secondary?
   ________ V
2. What current flows in the secondary circuit? ________ A
3. Now that you know the voltage and the current, what is the power in the secondary coil? ________ W
4. Neglecting small heating losses, and knowing that energy is conserved, what is the power in the primary coil? ________ W
5. Now that you know the power and the voltage across the primary coil, what is the current drawn by the primary coil? ________ A

Circle the correct answers:

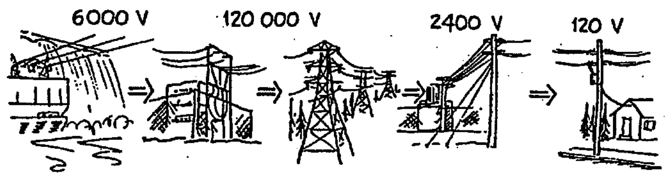
6. The results show voltage is stepped (up) (down) from primary to secondary, and that current is correspondingly stepped (up) (down).
7. For a step-up transformer, there are (more) (fewer) turns in the secondary coil than the primary. For such a transformer, there is (more) (less) current in the secondary than in the primary.
8. A transformer can step up (voltage) (energy and power), but in no way can it step up (voltage) (energy and power).
9. If 120 V is used to power a toy electric train that operates on 6 V, then a (step up) (step down) transformer should be used that has a primary to secondary turns ratio of (1/20) (20/1).
10. A transformer operates on (dc) (ac) because the magnetic field within the iron core must (continually change) (remain steady).

Conceptual PHYSICS

Name ____________ Period ______ Date ______

Concept-Development Practice Page 37-2

Power Transmission



Many power companies provide power to cities that are far from the generators. Consider a city of 100 000 persons who each use continually use 120 W of power (equivalent to the operation of two 60-W light bulbs per person). The power constantly consumed is 100 000 persons x 120 W / person = 12 million W (12 MW).

1. What current corresponds to this amount of power at the common 120 V used by consumers?

$P = IV$

$12\,000\,000\,W = I \times 120\,V$

$I = \frac{\rule{3cm}{0.4pt}\,W}{V} = \rule{2cm}{0.4pt}\,A$

This is an enormous current, more than can be carried in the thickest of wires without overheating. More power would be dissipated in the form of heat than would reach the faraway city. Fortunately the important quantity is *IV* and not *I* alone. Power companies transmit power over long distances at very high voltages so that the current in the wires is low and heating of the power lines is minimized.

2. If the 12 MW of power is transmitted at 120 000 V, the current in the wires is

$I = \frac{P}{V} = \frac{\rule{3cm}{0.4pt}\,W}{V} = \rule{2cm}{0.4pt}\,A$

This amount of current can be carried in long-distance power lines with only small power losses due to heating (normally less than 1%). But the corresponding high voltages wired to houses would be very dangerous. So step-down transformers are used in the city.

3. What ratio of primary turns to secondary turns should be on a transformer to step 120 000 V down to 2400 V? __________

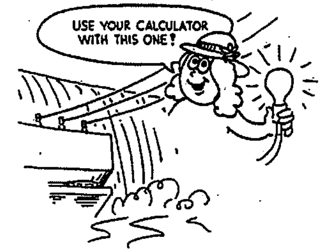
4. What ratio of primary turns to secondary turns should be on a transformer to step 2400 V down to 120 V used in household circuits? __________

5. What is the main benefit of ac compared to dc power?

____

Conceptual **PHYSICS**

Power Production



Does it take a lot of water to light a light bulb? That depends on its wattage and how long it glows. In this practice page, you are to calculate the mass and volume of water that falls over a 10-m high dam to keep a 100-W light bulb glowing for 1 year.

1. First, calculate how many joules are required to keep the bulb lit for 1 year.

$\text{Energy} = \text{power} \times \text{time} = 100\,W \times 1\,yr \times \frac{1\,J/s}{1\,W} \times \frac{365\,d}{1\,yr} \times \frac{24\,h}{1\,d} \times \frac{3600\,s}{1\,h}$

$= \rule{3cm}{0.4pt}\,J$

2. What mass of water elevated 10 m has this much PE? From Chapter 8, recall that gravitational PE = *mgh*:

$PE = mgh$

$m = \frac{PE}{gh} = \frac{\rule{3cm}{0.4pt}\,J}{(9.8\,m/s^2)(10\,m)} = \rule{3cm}{0.4pt}\,kg$

3. But this assumes 100% efficiency. A hydroelectric plant is typically 20% efficient. This means only 1 part in 5 of the PE of the falling water ends up as electricity. So the mass above must be multiplied by 5 to get the actual amount of water that must fall to keep the 100-W bulb lit.

$5 \times \rule{3cm}{0.4pt}\,kg = \rule{3cm}{0.4pt}\,kg$

4. This is an impressive number of kilograms! To visualize this amount of water, convert it to cubic meters. (Recall 1 kg of water occupies 1 liter, and there are 1000 liters in 1 cubic meter.)

$\text{Volume} = \rule{3cm}{0.4pt}\,kg \times 1\,\frac{L}{kg} \times \frac{1\,m^3}{1000\,L} = \rule{3cm}{0.4pt}\,m^3$

5. For comparison, an Olympic-size swimming pool holds about 4000 m^3 of water. How many such poolfuls of water are required to keep a 100-W bulb lit for one year?

$\text{Number of poolfuls} = \frac{\rule{3cm}{0.4pt}\,m^3}{m^3/\text{poolful}} \approx \rule{2cm}{0.4pt}\text{ poolfuls}$

Does it take a lot of water to light a light bulb? To light a city full of light bulbs? Now you have a better idea!

Conceptual **PHYSICS**

Physics Two (Gore) – Magnetic Forces Worksheet 7

Electromagnets

1. In **Figure 7.9**, the conductor on the left carries current 'into the page'. The conductor on the right carries current 'out of the page'.

Figure 7.9

(a) Draw sample lines of force around each conductor, showing their direction.
(b) Would these conductors attract each other or repel each other? Explain your answer. (Hint. If you place two bar magnets side by side so that the lines of force of their magnetic fields are in the same direction, how do the magnets affect each other?)

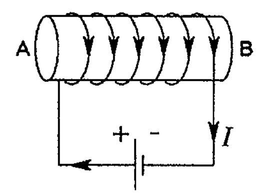


Figure 7.10

2. Which end of the solenoid (**A** or **B**) in **Figure 7.10** will be north?

Charged Particles in magnetic Fields

1. When the solenoid current in the arrangement used in ***Investigation 7-1*** is 2.2 A, the beam in the CRT is deflected 1.2 cm. What will the deflection be if the solenoid current is increased to 3.6 A?
2. The deflection on a CRT screen is 1.4 cm when the accelerating voltage is 500 V. If the solenoid current is kept constant, what will happen to the magnetic deflection if:
(a) the accelerating voltage is increased to four times its original value?
(b) the electron speed is increased four times?
3. The deflection on a CRT screen is 1.2 cm when the solenoid current is 1.5 A and the accelerating voltage is 500. V. If the solenoid current is changed to 3.0 A, what accelerating voltage is needed to maintain the same deflection?

Magnetic Field Strength

1. An electron traveling with a speed of 2.0×10^6 m/s moves in a direction perpendicular to a magnetic field of strength 2.5×10^{-2} T.
(a) What is the force acting on the electron?
(b) What is the magnitude and the direction of the acceleration?
2. A proton traveling at a speed of 3.0×10^6 m/s travels through a magnetic field of strength 3.0×10^{-3} T, making an angle of 45° with the magnetic lines of force. What force acts on the proton?

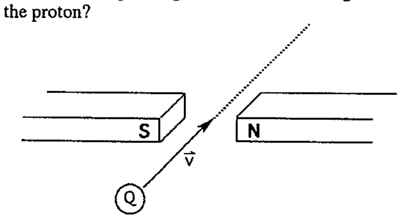


Figure 7.15

3. (a) A beam of alpha particles (He^{2+}) is traveling between the magnetic poles in **Figure 7.15**. In what direction will the alpha particles be deflected?
(b) If magnetic field strength is 6.4 T, and the alpha particles move with a speed of 6.0×10^7 m/s, what will the magnetic force on the alpha particles be?

Solenoids

1. A solenoid is 15.0 cm long and has 250 turns. What is the magnetic field strength inside the solenoid if the current in the coils is 3.8 A?
2. A solenoid is to be wound on a cardboard form 30.0 cm long. How many turns of wire are needed to produce a magnetic field of 6.28×10^{-3} T, if the maximum allowable current is 5.0 A?
3. A solenoid 40.0 cm long has a magnetic field of 5.0×10^{-3} T when the current in it is 10.0 A. How many turns of wire does it have?
4. What magnetic field strength is needed to exert a force of 1.0×10^{-15} N on an electron traveling 2.0×10^7 m/s?

Current Balance

1. (a) A solenoid 15.0 cm long has 600 turns and carries a current of 5.0 A. What is the magnetic field strength inside this coil?
(b) A 2.0 cm segment of a current balance arm is balanced inside the solenoid when the current in it is 3.0 A. What is the magnetic force on the segment?
2.A 61 mg mass just balances the balance arm of a current balance when the strip current is 3.0 A. If the strip is 2.2 cm long, what is the magnetic field strength inside the solenoid in which the current balance is located?
3. The magnetic field strength inside a certain solenoid is 0.025 T. If a 3.2 cm conducting strip, which is perpendicular to the magnetic field inside the solenoid, experiences a force of 5.9×10^{-4} N, what is the current in the conducting strip?
4. A conductor 25 cm long carries a current of 50.0 A. It is placed in a magnetic field of strength 49 T. What force is exerted on the conductor if it makes these angles with the magnetic lines of force? (a) 0° (b) 45° (c) 90°

5. (a) A 5.0 cm segment of wire carrying 2.5 A is perpendicular to a magnetic field of 25 T inside a solenoid. What is the magnetic force on the segment?
   (b) If the current inside the solenoid is increased to five times its original value, what will the new magnetic field strength be?

Magnetic Fields

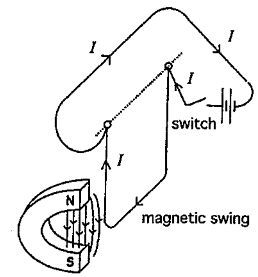
1. A magnetic field of strength 4.34×10^{-3} T makes electrons deflect into a circular path of radius 1.1×10^{-2} m. The accelerating voltage used to get the electrons up to maximum speed was 200.0 V. If the charge on an electron is 1.6×10^{-19} C, what is the mass of an electron?
2. A beam of protons passes through a magnetic field of strength 4.0×10^{-3} T, and is deflected into a curved path of radius 1.14 m. If the accelerating voltage was 1.0×10^{3} V, what is the mass of a proton?
3. If the proton in **Exercise 2** were replaced by deuterium ions that have twice the mass of a proton but carry the same charge, what would the radius of curvature of the magnetically deflected deuterium ions be, in the same circumstances?
4. Protons are accelerated and made to pass through crossed fields where the electric field is perpendicular to the magnetic field, and the protons are moving at such a speed that the magnetic force just equals the electric force, but is in the opposite direction, so that there is no overall deflection of the beam. What speed do the particles have if B = 0.50 T and $E = 5.5 \times 10^{4}$ N/C? (Such a device was used by J. J. Thomson when he was measuring the charge-to-mass ratio of electrons. It is called a **velocity selector.**)

Mass Spectrometer

1. Two isotopes of hydrogen are present in a particle beam issuing through the final slit into the magnetic field outside the velocity selector of a mass spectrometer. Protons and deuterons, both with a charge of +1, are subjected to the same magnetic field strength. Both go into a circular path. If the proton path radius is R, what will the deuteron path radius be? (A deuteron is a deuterium nucleus, which consists of a proton and a neutron.)
2. What is the velocity of ions that pass successfully through a velocity selector, if the electric field has strength 1.5×10^{5} N/C and the magnetic field in the velocity selector is 0.50 T? What will the radius of the path of these ions be, if the bending magnet has a field strength of 0.75 T? Assume the ions have a charge of +e, and an atomic mass of 20 **u**, where 1 **u** = 1.67×10^{-27} kg.

Chapter Review

1. Name at least three ferromagnetic elements.
2. If you wanted to accelerate a stationary proton, would you use an electric field or a magnetic field? Explain.
3. Draw a diagram showing a conductor with conventional current moving ***into your page***. Draw a few sample lines of magnetic force around the conductor, including their directions.
4. Describe the magnetic field inside a long solenoid.
5. Draw a solenoid with current moving in a direction of your choice. Label the north end of the solenoid.



6. When the switch is closed on this 'magnetic swing', will it move 'out' from the poles of the magnet or 'in' toward the magnet? Use the Right Hand Motor Rule.

Figure 7.30

7. An electron moving with a speed of 0.10 c moves through a magnetic field of strength 0.60 T. What force acts on the electron?
   ($c = 3.0 \times 10^{8}$ m/s) ($e = 1.6 \times 10^{-19}$ C)
8. A solenoid is wound with 100 turns per centimetre. What is the magnetic field strength inside the solenoid when it carries a current of 5.0 A? ($\mu_0 = 4\pi \times 10^{-7}$ T· m/A)
9. A magnetic field from a solenoid is used to deflect a beam of electrons 0.80 cm on the screen of a CRT. If the current in the solenoid is doubled, what will the deflection be then?
10. An electron beam in a CRT is deflected 0.64 cm when the accelerating voltage is 500.0 V. By how much will the beam be deflected if the magnetic field is kept constant but the accelerating voltage is increased to 2000.0 V?
11. What is the magnetic force exerted on a segment of wire 12 cm long in a perpendicular magnetic field of strength 36 T, if the wire carries a current of 6.0 A?
12. If the force on a 5.0 cm piece of wire carrying 12 A is 1.0×10^{-3} N, what is the magnetic field strength of the perpendicular field through which the current passes?
13. A conducting wire 1.0 m long carries a current of 7.5 A. It is placed in a magnetic field of strength 5.0×10^{-5} T. If the wire makes an angle of 60° with the magnetic lines of force, what is the force acting on the wire?
14. A 75 mg mass just balances the strip in a current balance when the current in the strip is 2.5 A. If the strip is 2.0 cm long, what is the magnetic field strength inside the solenoid in which the current balance is located?
15. An alpha particle is accelerated by a voltage of 1.53×10^{3} V and is then deflected by a magnetic field of strength 0.020 T into a circular path of radius 0.40 m. If the alpha particles have a charge of 3.2×10^{-19} C, what is their mass?
16. Why does a DC motor need a split-ring commutator?
17. Two parallel wires carry currents in the *same* direction. Will the wires attract or repel each other? Explain with the help of a diagram.
18. In the velocity selector part of a mass spectrometer, a field of 0.65 T is used for magnetic deflection of a beam of protons travelling at a speed of 1.0×10^{6} m/s. What electric field is needed to balance the force due to the magnetic field? If the distance

between the plates of the electrical deflection apparatus is 0.50 cm, what voltage must be applied to the plates?

19. What speed must electrons in a beam of electrons going through a velocity selector have, if the beam is undeflected by crossed electric and magnetic fields of strengths 6.0×10^3 V/m and 0.0030 T respectively? If the electric field is shut off, what would the radius of the beam become due to the unbalanced magnetic force?

Answers

Electromagnets

1. (a) Lines are circular and clockwise around the conductor with current going into the page, and counterclockwise around the conductor with current coming out of the page.
   (b) Repel. Lines of force in the space between the conductors run in the same direction (*down* on the diagram), just as they would with two bar magnets lined up with like poles adjacent to each other.
2. End **B** is north.

Charged Particles in Magnetic Fields

1. 2.0 cm
2. (a) 0.70 cm (b) 0.35 cm
3. 2.0×10^3 V

Magnetic Field Strength

1. (a) 8.0×10^{-15} N (b) 8.8×10^{15} m/s^2, perpendicular to the velocity.
2. 1.0×10^{-15} N
3. (a) Up, perpendicular to magnetic field lines.
   (b) 1.2×10^{-10} N

Solenoids

1. 8.0×10^{-3} T
2. 300 turns
3. 159 turns
4. 3.1×10^{-4} T

Current Balance

1. (a) 2.5×10^{-2} T (b) 1.5×10^{-3} N
2. 9.1×10^{-3} T
3. 0.74 A
4. (a) 0 (b) 4.3×10^2 N (c) 6.1×10^2 N
5. (a) 3.1 N (b) 125 T

Magnetic Fields

1. 9.1×10^{-31} kg
2. 1.7×10^{-27} kg
3. 1.6 m
4. 1.1×10^5 m/s

Mass Spectrometer

1. 2*R*
2. (a) 3.0×10^5 m/s (b) 8.4 cm

Chapter Review

1. iron, cobalt, nickel.
2. Electric field. A constant magnetic field will not affect a stationary charged particle.
3. Lines of force are clockwise and circular.
4. Lines are parallel for the length of the solenoid, going from **S** to **N** *inside* the solenoid.
6. 'Out'.
7. 2.9×10^{-12} N
8. 6.3×10^{-2} T
9. 1.60 cm
10. 0.32 cm
11. 26 N
12. 1.7×10^{-3} T
13. 3.2×10^{-4} N
14. 1.5×10^{-2} T
15. 6.7×10^{-27} kg
17. Attract
18. 6.5×10^5 V/m, 3.3×10^3 V
19. 2.0×10^6 m/s, 3.8 mm

Physics Two (Gore) – Electromagnetic Induction

Induced Emf

1. An aircraft with a wingspan of 30.0 m travelling 250 m/s dives perpendicular to the lines of force of the earth's magnetic field (5.0×10^{-5} T). What emf is induced between the two wing tips?
2. A 15 cm piece of wire is moved through the poles of a 0.40 T magnet with a speed of 5.0 m/s. What is the potential difference between the ends of the wire?
3. How fast would you have to move a 0.50 m wire perpendicular to the earth's magnetic field (5.0×10^{-5} T) in order to induce an emf of 1.5 V?
4. In **Figure 8.5 (b)**, in which direction would **electrons** tend to move along the segment of wire? (***Into*** the page or ***out of*** the page?)

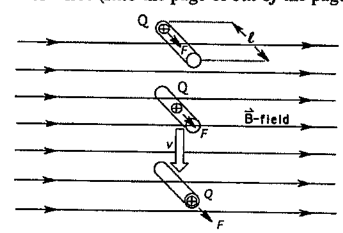


Figure 8.5 (b)

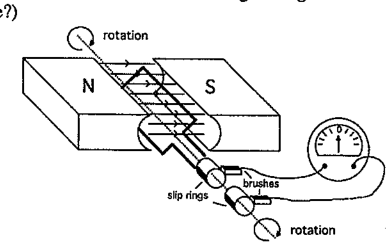


Figure 8.6

Generators

1. How might you convert the generator in **Figure 8.6** so that instead of producing alternating emf and current it will produce direct current? Would it be a steady D.C.? Sketch a graph to show how the emf would vary with time.
2. Start with the formula for the induced emf of a generator: $\mathcal{E} = 2NB\ell v \sin\theta$. The speed of a segment of the coil can be calculated from $v = 2\pi R/T$, where R is the radius of the circle traced out by the rotating segment, and T is the period of the rotation. Write an equation for the emf induced by a generator in terms of the frequency (*f*) of rotation of the coil.
3. Assuming the coil in a generator is rectangular, its area would equal its length times its total width; that is $A = 2\square r$. Rewrite your equation from **Exercise 2** in terms of the *area* of the coil.
4. The armature of a 60 Hz AC generator rotates in a magnetic field of strength 0.48 T. If the area of the coil is 2.4×10^{-2} m^2 and it contains 120 loops, what will the peak emf be?
5. List four factors you could change to increase the emf produced by a generator. Tell how you would change them.

Faraday's Law

1. A square loop with sides 12 cm by 12 cm has 25 turns of wire and is in a magnetic field of strength 4.2×10^{-2} T with its axis perpendicular to the direction of the field. If

it is rotated in 0.15 s so that its axis is parallel to the field, what is the average induced emf during this quarter turn of the loop?

2. The magnetic flux in a coil of 50 turns changes from – 0.56 Wb to + 0.14 Wb in a time of 7.0 ms. What is the average induced emf?

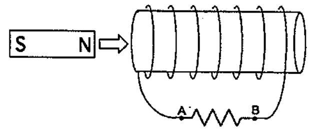


Figure 8.12

3. When the magnet in **Figure 8.12** is moved to the right toward the inside centre of the solenoid, in what direction will conventional current in the resistor move? Explain.

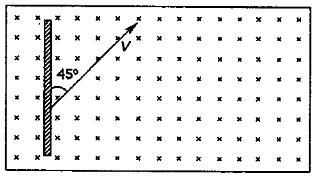


Figure 8.13

4. (a) A wire 7.8 cm long moves with a velocity of 2.4 m/s through a magnetic field of strength 0.68 T, which is directed ***into the page*** on the above diagram. The velocity vector makes an angle of 45° with the wire. What is the magnitude of the induced emf in the wire?
   (b) Which end of the wire will become positively charged?
   (c) What is the magnitude and direction of the **electric** field in the wire?

Counter Emf

1. An electric motor is operated from a 6.0 V supply. When the armature is held still, the current in it is 4.0 A. When the armature is allowed to turn freely, the current is 2.4 A.
   (a) What is the resistance of the armature?
   (b) What is the 'back emf' of the motor at this frequency of rotation?
   (c) If the load on the motor is increased so that its frequency is reduced to three quarters of what it was, what will the 'back emf' be then?
2. A motor has an armature resistance of 1.8 Ω. Running at full speed, it draws a current of 0.50 A when connected to a 12.0 V source. What is the 'back emf'?
3. In **Exercise 2**, what will the 'back emf' be if the motor runs at half its normal frequency?
4. The 'back emf' of a motor is 4.2 V when operated from a 6.0 V source. When held stationary, the current in the motor's armature is 5.0 A.
   (a) What is the resistance of the armature?
   (b) What current will exist in the armature when it is rotating at normal speed?
5. Why might overloading a motor actually destroy the armature of the motor?
6. The input power for a motor is IV, where I is the current and V is the source voltage. The power lost as heat in the armature is I^2R. The power output of the motor is therefore $IV - I^2R$. The **efficiency** of the motor equals the ratio of power output to power input. Show that this ratio reduces to E_B/V.
7. Is an electric motor more efficient at high frequency or low frequency? Explain.

Transformers (Assume all transformers are 100% efficient)

1. Why will a transformer not work with DC current?
2. A transformer has 120 turns in the primary coil and 600 turns in the secondary coil. If 120 V is applied to the primary coil, what will the secondary coil voltage be?
3. The primary coil of a transformer has 5 000 turns and the voltage across it is 120 V. The secondary coil has 50 turns.
   (a) What is the voltage across the secondary coil?
   (b) What is the primary coil current if the current in the secondary coil is 10.0 A?
4. A transformer has 50 primary turns and 2 000 secondary turns. The primary coil is connected to a 240 V source. If the secondary current is 2.5 mA, what is the
   (a) secondary voltage?
   (b) primary current?
   (c) power output of the secondary coil?
   (d) power input at the primary coil?
5. Why is a step-down transformer inserted between your circuit box and your doorbell circuit?
6. Find out why the iron core of a transformer is made in insulated layers (laminated) instead of one solid block of steel. What are 'Eddy currents'?

Chapter Review

1. A straight piece of wire 10.0 cm long is moved through the poles of a magnet of strength 0.25 T at a speed of 4.0 m/s. What emf is induced between the ends of the wire? What is the **electric field strength** in the wire while it is moving?
2. What is the difference between **magnetic field strength** and **magnetic flux**?
3. What is **Faraday's Law of Induction** (a) in symbols and (b) in words?
4. What is **Lenz's Law**?
5. A loop of area 225 cm^2 has 24 turns of wire. It is in a magnetic field of strength 3.6×10^{-2} T. To begin with, its plane (face) is parallel to the lines of force of the field. In a time of 0.15 s it is rotated so that its plane is perpendicular to the lines of force. What is the average emf induced in the loop during the one-quarter rotation?
6. Draw a solenoid with a few representative turns. A permanent magnet is moving toward it from the right, with the south pole about to enter the solenoid. What will be the polarity of the right end of the solenoid at this instant? Sketch which way current will move in the solenoid if it is connected to a conducting path.
7. By how much must the **magnetic flux** inside a coil of 100 turns change in a time of 1.0 ms to produce an emf of 2.0 V?
8. What is the peak emf of a generator that has a frequency of 60 Hz, a magnetic field strength of 0.64 T, a coil of area 0.120 m^2, and 250 turns in its coil?

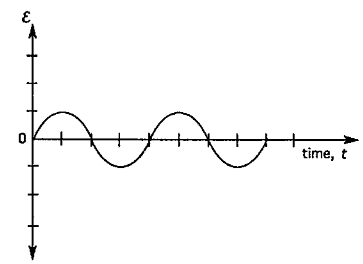


Figure 8.18

9. **Figure 8.18** shows how the emf produced by an AC generator varies with time. Sketch this graph, then show on the same diagram how this graph would change if ***both*** the number of turns on the generator's rotating armature ***and*** the frequency of rotation of the armature were doubled.
10. The armature resistance of a motor is 1.8 Ω. If the source voltage is 12.0 V, what is the back emf of a motor that draws 2.0 A when running at full speed?
11. What is the efficiency of a motor if its back emf is 8.0 V when the source voltage is 12.0 V?
12. The back emf of a motor is 6.3 V when the current is 3.0 A. What is the armature resistance if the source voltage is 9.0 V?
13. The armature of a DC motor has a resistance of 5.0 Ω. The motor is connected to a 120 V line, and when the motor reaches full speed the back emf is 108 V.
    (a) What is the current at 'start-up' (before the motor turns over)?
    (b) What is the current when the motor is being used?
14. The primary voltage of a step-up transformer is 120 V. There are 50 turns in the primary coil and 800 turns in the secondary coil.
    (a) What is the output voltage in the secondary?
    (b) What is the current in the secondary if the primary coil current is 16 mA?
    (c) What is the power input to the primary coil?
15. A transformer has 400 primary turns and the input voltage to the primary coil is 120 V. The secondary coil voltage is 6 000 V. How many turns are there in the secondary coil?
16. A transformer has an efficiency of 98%. A primary voltage of 240 V is stepped down to 12.0 V. If the secondary current is 20.0 A, what is the primary current?
17. A coil of radius 0.072 m and with 36 turns is in a magnetic field of 0.80 T. If the coil is completely removed from the field in a time of 20.0 ms, what is the induced emf in the coil?
18. If the magnetic flux through a coil of wire with 300 turns changes from + 5.0 Wb to – 10.0 Wb in a time of 0.050 s, what emf is induced in the coil?
19. The magnetic field perpendicular to a coil of wire with radius 4.2 cm and with 24 turns changes from + 0.25 T to – 0.25 T in a time of 0.15 s. What is the magnitude of the induced emf?

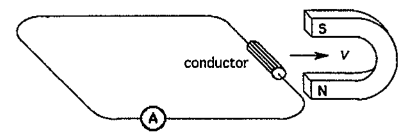


Figure 8.19

20. Will the induced current in the conductor in **Figure 8.19** be 'into the page' or 'out of the page'? Explain why.
21. A voltage of 12 V is applied to an electric motor with an armature resistance of 5.0 Ω. When the armature is rotating at its peak speed, the current in it is 0.48 A. When a load is placed on the motor, its speed (frequency) is reduced to 1/3 of its peak speed. What is the 'back emf' of the motor under this load?
22. A town receives 10 MW of power delivered at 50 kV from a generator over lines which have a resistance of 5.0 Ω. What percentage of the power generated is lost as heat in the lines?

Answers

Induced Emf
1. 0.38 V
2. 0.30 V
3. 60 km/s!
4. Into the page.

Generators
1. Use a split-ring commutator.

2. E = 4πNBℓfRsinθ
3. E = 2πNABfsinθ
4. 5.2 x 10^2 V
5. Increase *any* of *N, B, A* or *f.*

Faraday's law
1. - 0.10 V
2. - 5.0 x 10^3 V
3. A to B. Left end becomes north (Lenz's Law) Ampère's Right Hand Rule indicates current is from A to B.
4. (a) 0.090 V
   (b) Top end (Lenz's Law, Ampère's Rule)

(c) 1.2 V/m

Counter Emf
1. (a) 1.5 Ω (b) 2.4 V (c) 1.8 V
2. 11.1 V
3. 5.6 V
4. (a) 1.2 Ω (b) 1.5 A
5. Overloading decreases *f,* which decreases back emf and increases current *I,* which may burn out the armature.
6.

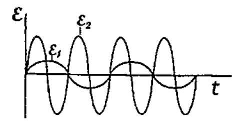
$$\text{Efficiency} = \frac{IV - I^2R}{IV} = \frac{I(V - IR)}{IV} = \frac{\varepsilon_B}{V}$$

7. Since Efficiency = E_B / V, and $E_B \propto f$, therefore efficiency increases at higher frequency.

Transformers
1. With DC, the rate of change of magnetic flux is zero, therefore the induced emf is zero also.
2. 600 V
3. (a) 1.20 V (b) 0.10 A
4. (a) 9.6 x 10^3 V (b) 100 mA
   (c) 24 W (d) 24 W
5. Lower voltage is safer.
6. Reduces 'eddy currents' in the iron, that may cause energy loss as heat, I^2Rt.

Chapter Review

1. 0.10 V, 1.0 V/m
2. $\phi = BA$
3. E = $\square$. See text.
4. See text.
5. - 0.13 V
6. Right end is south.
7. -2.0×10^{-5} Wb
8. 7.2×10^{3} V



9. $E_2 = 4E_1$ and $t_2 = \frac{1}{2}t_1$
10. 8.4 V
11. 0.67
12. 0.90 Ω
13. (a) 24 A (b) 2.4 A
14. (a) 1.92×10^{3} V
    (b) 1.0 mA
    (c) 1.9 W
15. 2.0×10^{4} turns
16. 1.02 A
17. 23 V
18. 9.0×10^{4} V
19. 0.44 V
20. Out of page (Lenz's Law, Ampere's Right Hand Rule)
21. 3.2 V
22. 2.0 %