Grade 10 Advanced Inspire Physics Academic Year 2022-2023– Term 3 REVISION PPT

An exam is not only a test
Of your academic knowledge
It is also a test of your
Calmness, stability and courage...

Good Luck
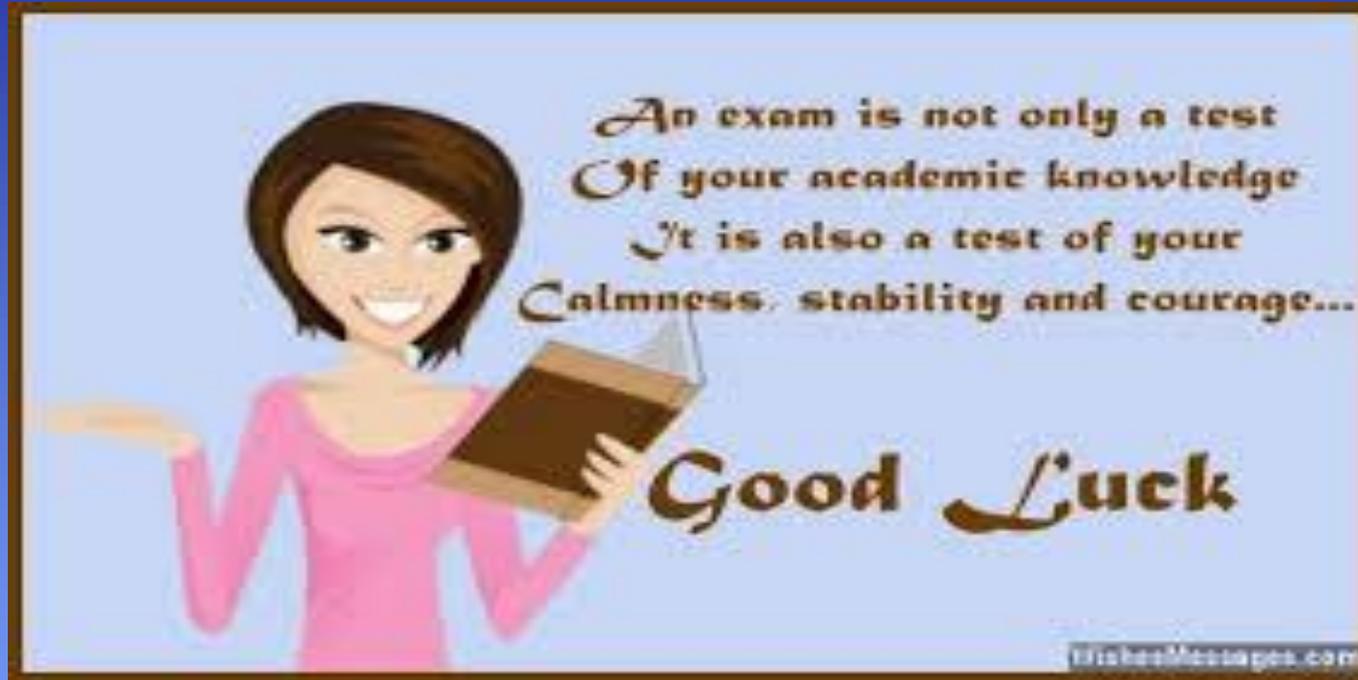
DONE BY MS. SUVARNA JOY. K
IBN HAZEM BOYS SECONDARY SCHOOL, AJMAN.
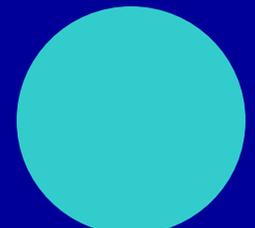
PART 1

| 1	Apply the right-hand rule to determine the direction of the induced current in a wire (that is part of a clost circuit) moved in a magnetic field.	As mentioned in the textbook	153
2	Define electromotive force emf and speciify its unit as volts (V).	As mentioned in the textbook	153
3	Describe the primary characteristics of electromagnetic waves.	As mentioned in the textbook	177
4	Draw a sketch of emf (or current) versus time for an AC generator, relating the position of the coil to the emf (or current) induced.	As mentioned in the textbook	158
5	Determine the type of pole induced on the face of a coil and the direction of induced current in a coil when a coil and a magnet are in relative motion.	As mentioned in the textbook	161
6	Explain how bright and dark interference fringes are created in a double-slit interference investigation with monochromatic light.	As mentioned in the textbook	194-195

Magnitude of current Recall that resistance is equal to potential difference divided by current. Thus, if an *EMF* generates a current in a wire that is part of a circuit with an effective resistance *R*, and you know the *EMF*, you can determine the current's magnitude by the following equation:

$$I = \frac{EMF}{R}$$

Direction of current How do you determine the direction of an induced current in a wire? As a wire moves through a magnetic field, a force is exerted on the charges in the wire, and they move in the direction of that force, as shown in the top image of **Figure 2**. To find this direction, use the right-hand rule illustrated in the bottom of **Figure 2**. Point your thumb in the direction the wire moves and your fingers in the direction of the magnetic field. Your palm points in the direction of the force on the positive charges and, thus, in the direction of current.

Figure 2 The direction of current in a wire moving through a magnetic field can be found using a right-hand rule. Note that the direction of current is the same as the direction of the force on the charges in the wire.

Direction of Current

Right-Hand Rule
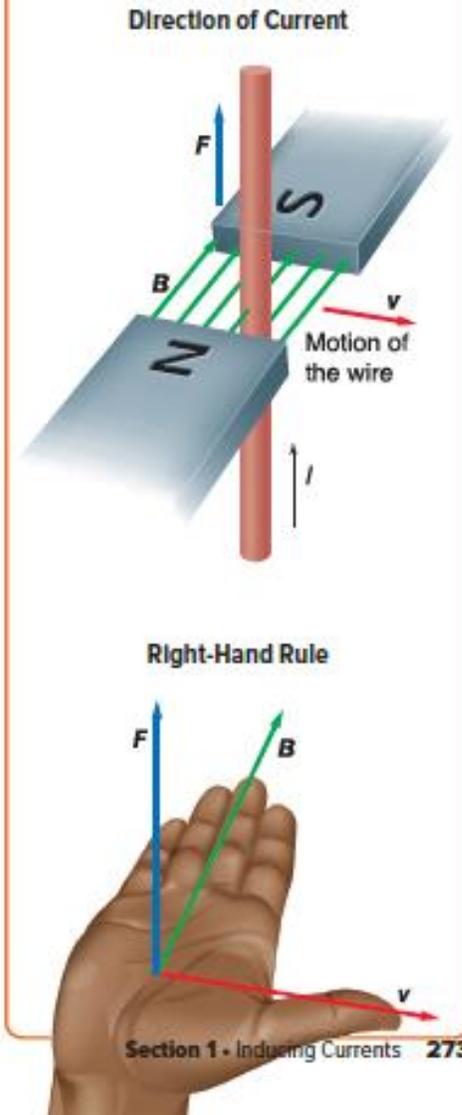
Electromotive force How is current produced by electromagnetic induction? You know that a current requires a source of electrical energy, such as a battery. A battery maintains an electric potential difference in a circuit; charges flow from higher to lower potential. The potential difference across the battery's terminals is the electromotive force, or *EMF*. An *EMF* is a difference in potential, not actually a force. Like many historical terms, it was coined before related principles were well understood.

emf = Potential difference

Its Unit is Volts (V)

Induced *EMF* You don't need a chemical reaction in a battery to create an *EMF*. When a wire moves perpendicular to a magnetic field, there is a force on the charges in the wire. The force causes negative charges to move to one end of the wire, leaving positive charges at the other end. This separation of charge produces an electric field and therefore a potential difference across the length of the wire. This potential difference is called the **induced electromotive force,** or induced *EMF*.

The magnitude of an induced *EMF* in a wire in a magnetic field depends on the strength of the magnetic field (B), the length of the wire within the field (L), and the component of the velocity of the length of wire that is perpendicular to the field ($v(\sin \theta)$).
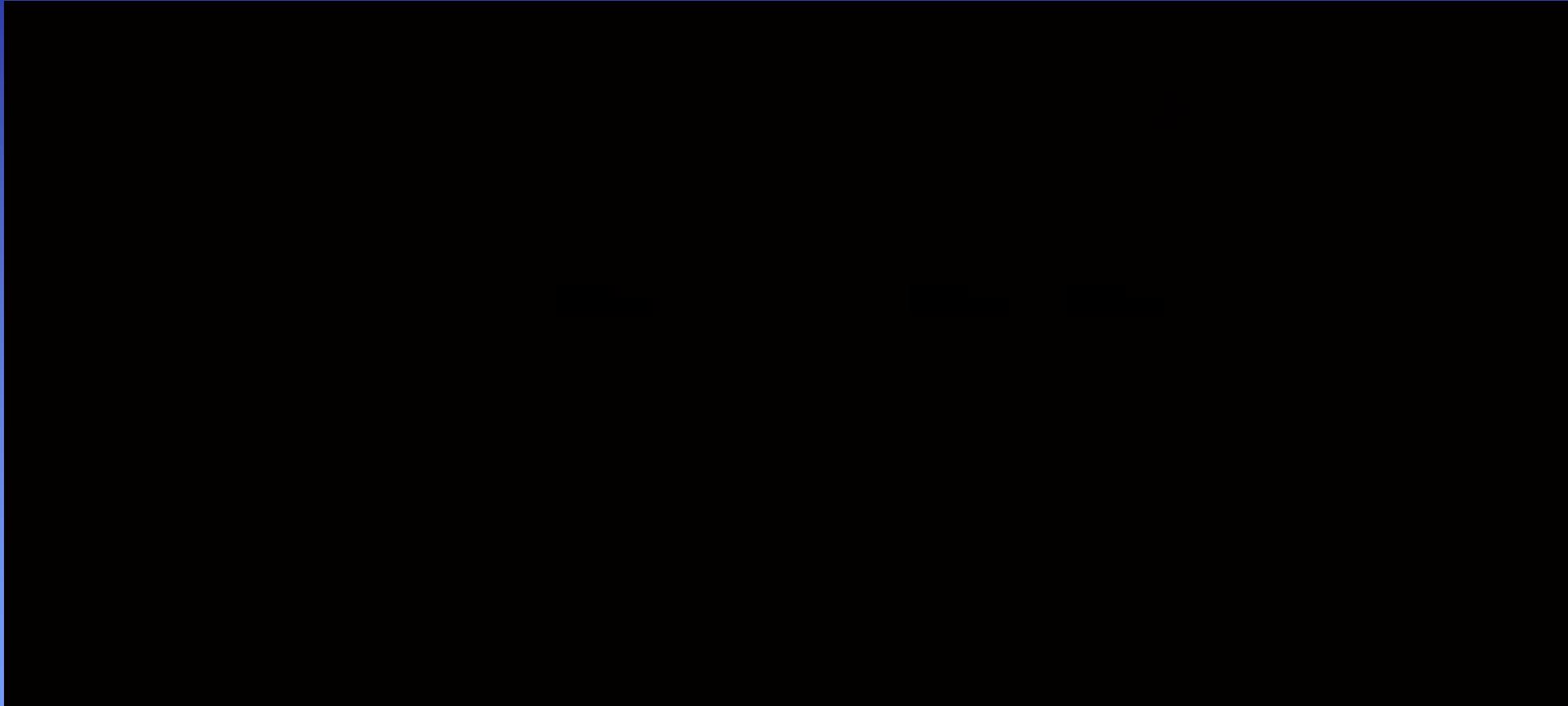
INDUCED ELECTROMOTIVE FORCE IN A WIRE

EMF is equal to the strength of the magnetic field times the length of the wire times the component of the velocity of the wire in the field that is perpendicular to the field.

$$EMF = BLv(\sin \theta)$$

If a wire moves perpendicular to a magnetic field, the above equation reduces to $EMF = BLv$, because $\sin 90° = 1$. Note that no *EMF* is induced in a length of wire that moves parallel to a magnetic field because $\sin 0° = 0$.

As in a battery, induced *EMF* is measured in volts (V). Why? Recall that magnetic fields (B) are measured in teslas (T). You can write $B = \frac{F}{IL}$, so the units for B are also N/(A·m). Velocity is measured in meters per second.
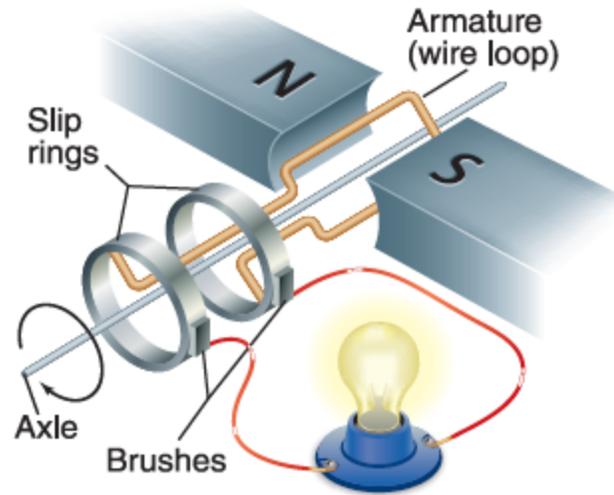
# Describe the primary characteristics of electromagnetic waves

Electric Generators

Microphones are just one of many technologies that rely on electromagnetic induction. Electromagnetic induction is also the principle governing the operation of electric generators.

An **electric generator** converts mechanical energy to electrical energy. It consists of a number of wire loops in a magnetic field. The wire is wound around an iron core, which concentrates the magnetic flux through the wire. The iron and wire make up the generator's armature, also called a rotor.

Current from a generator Like an armature in a motor, the armature in a generator can rotate freely in a magnetic field. As the armature is turned, its wire loops cut through magnetic field lines. This induces an *EMF* in each loop. Recall that *EMF* depends on wire length, magnetic field strength, and speed. Therefore, increasing the number of loops increases wire length and thus increases the total induced *EMF*. The larger the *EMF*, the stronger the resulting current.

Figure 8 This AC generator is similar in construction to an electric motor except it connects to a circuit using a brush-slip-ring device instead of a commutator. As the armature rotates, the direction of the current alternates in time (top right). The power delivered by the generator is always positive (bottom right).

Identify In what position is the armature when current is zero?

Current reversals As the loop in **Figure 5** rotates to the vertical position, it moves through the magnetic field lines at an ever-decreasing angle. Thus, it cuts through fewer magnetic field lines per unit of time, and the current decreases. When the loop is in the vertical position, as it is in the middle image of **Figure 5**, current is zero because the wire moves parallel to the magnetic field.
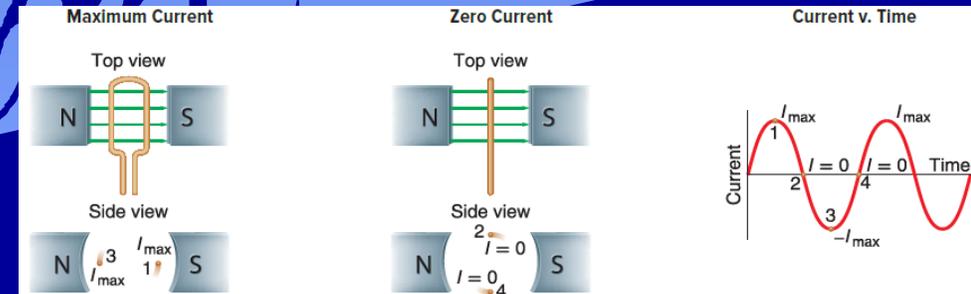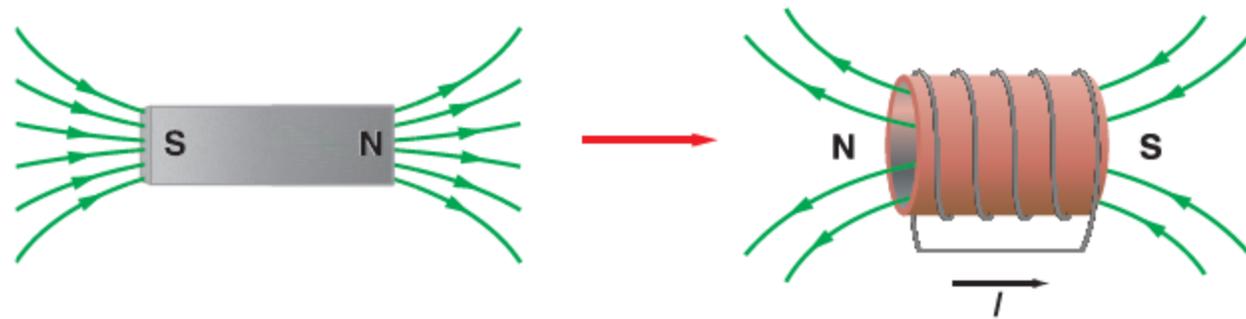
Figure 10 The magnet approaching the coil induces a current in the coil. The right-hand rule shows that the current is in the counter-clockwise direction. The current produces a magnetic field in the direction opposite the change in the field that produced it.

Lenz's law explains the direction of the current in the coil of wire in **Figure 10.** The approaching magnet causes an increase in the magnetic field inside the coil. The current produced by the induced *EMF* must be in the direction shown in **Figure 10** to produce a magnetic field that opposes the increase in field. The induced field exerts a repelling force on the approaching magnet. By Newton's third law, there must be an equal and opposite force on the coil. This force pushes the coil away from the magnet. If you moved the magnet away from the coil, the field within the coil would decrease. By Lenz's law the induced field would oppose this change by being in the same direction as the field of the magnet and adding to the field. In this case, the current producing the induced field in the coil would be in the clockwise direction.

Light from a monochromatic source produces incoherent light. Placing a light barrier with a narrow slit in front of the monochromatic light produces coherent light. Because the width of the slit is very small, only light from a tiny region of the source passes through the slit. Diffraction by the slit produces nearly cylindrical wavefronts, as shown in **Figure 4.**

The second barrier has two very small slits. Because a cylinder is symmetrical, the two portions of the wavefront arriving at the second barrier are in phase. The two slits at the second barrier produce nearly cylindrical wavefronts. These two wavefronts can then interfere, as shown in **Figure 4.** Depending on their phase relationship, the two waves undergo constructive or destructive interference, as shown in **Figure 5.** If the interference is constructive when the light hits a screen, you will see a bright band. If it is destructive, you will see a dark band.
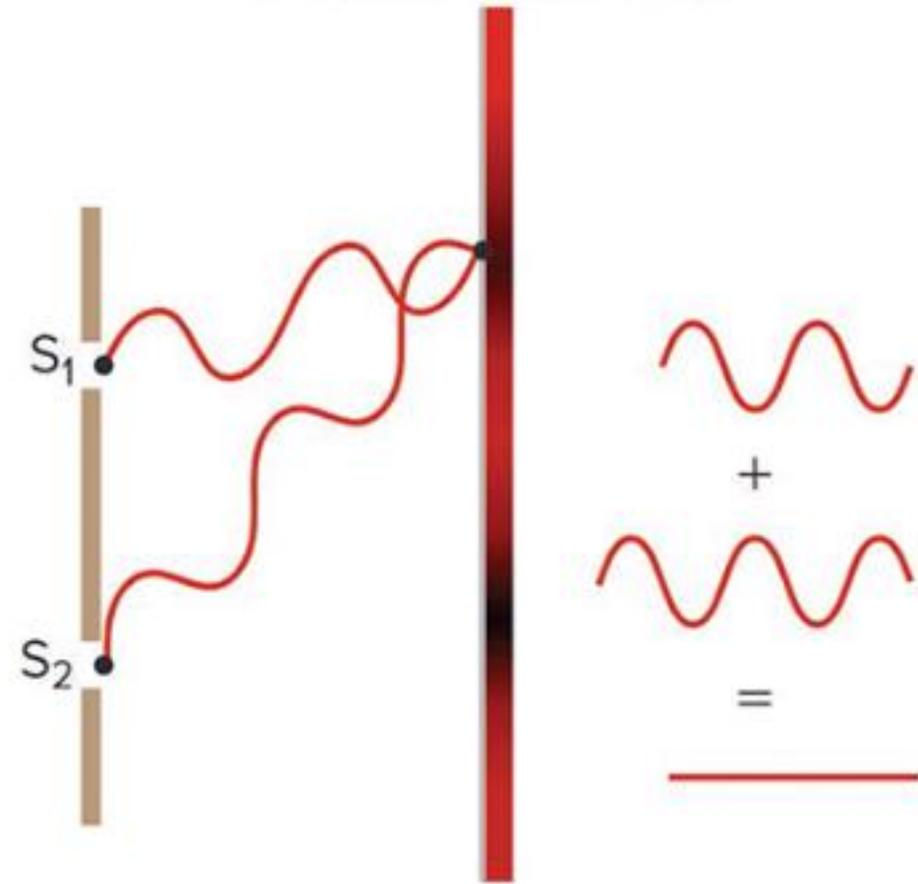

Figure 4 Nearly cylindrical wavefronts are generated as light passes through the slits.

Constructive Interference

S_1

S_2

+

=
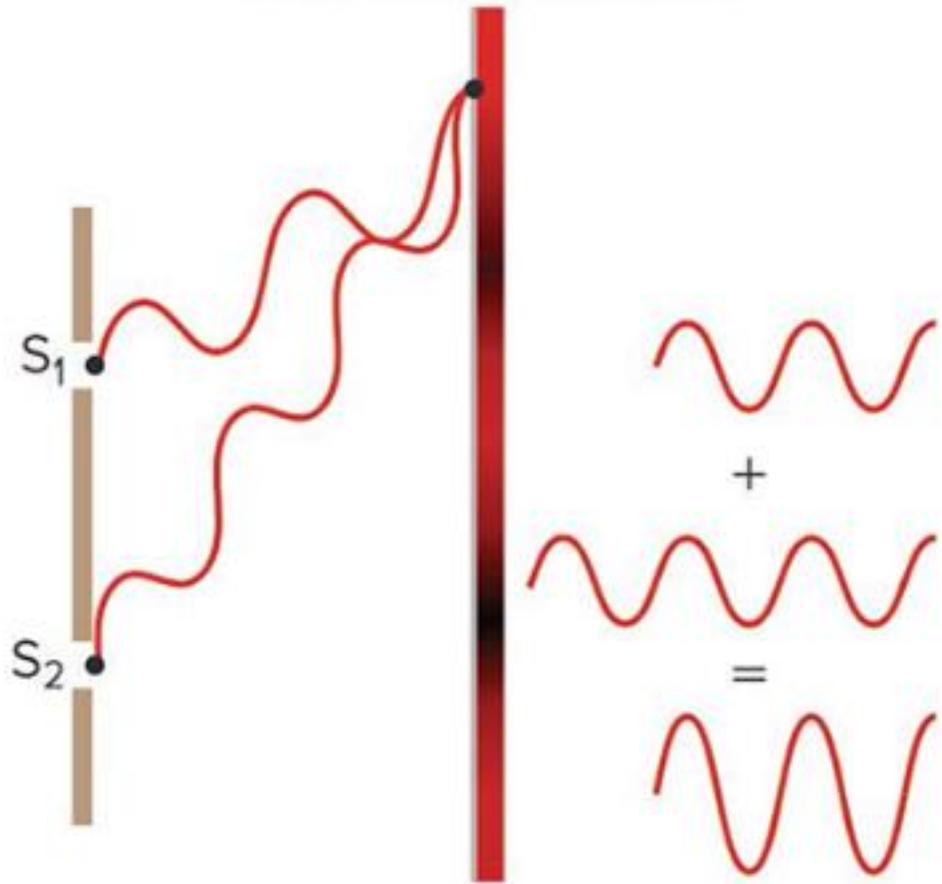
At the points where the waves experience constructive interference, bright bands are seen.

Destructive Interference

S_1

S_2

+

=

At the points where the waves experience destructive interference, dark bands are seen.

A top view of the double-slit investigation is shown on the left in **Figure 6.** The wavefronts interfere constructively and destructively to form a pattern of light and dark bands. The right side shows that light that reaches point P_0 travels the same distance from each slit. Because the waves are in phase, they interfere constructively on the screen to create the central bright band at P_0. There is also constructive interference at the first bright band (P_1) on either side of the central band because line segment $P_1 S_2$ is one wavelength (λ) longer than the line segment $P_1 S_1$. Thus, the waves arrive at P_1 in phase.

Double-Slit Interference Top View

Destructive interference - - - - - - - - -

Constructive interference _____

Source

S_1

S_2

Screen

Dark
Bright
Dark
Bright
Dark
Bright
Dark

Bright-Band Analysis

P_1

S_1

d Q

θ θ

R

S_2
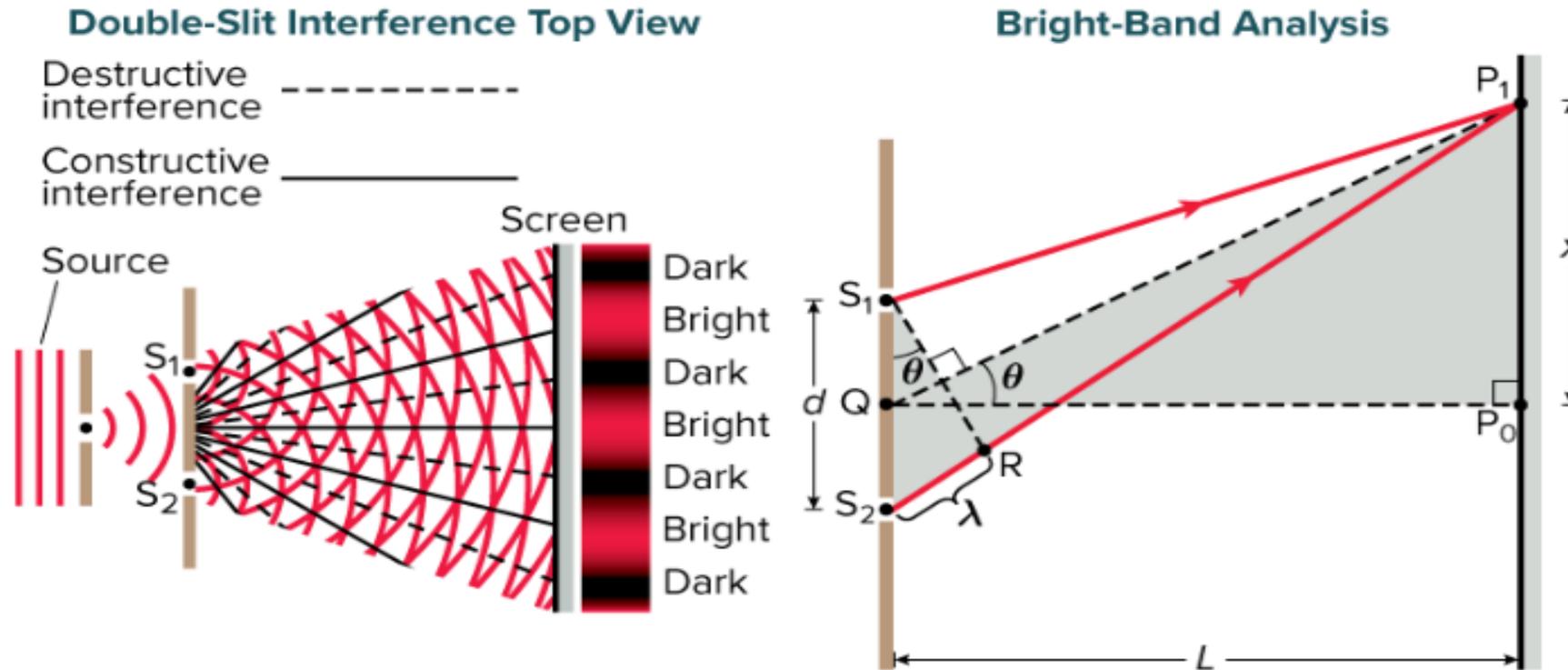
λ
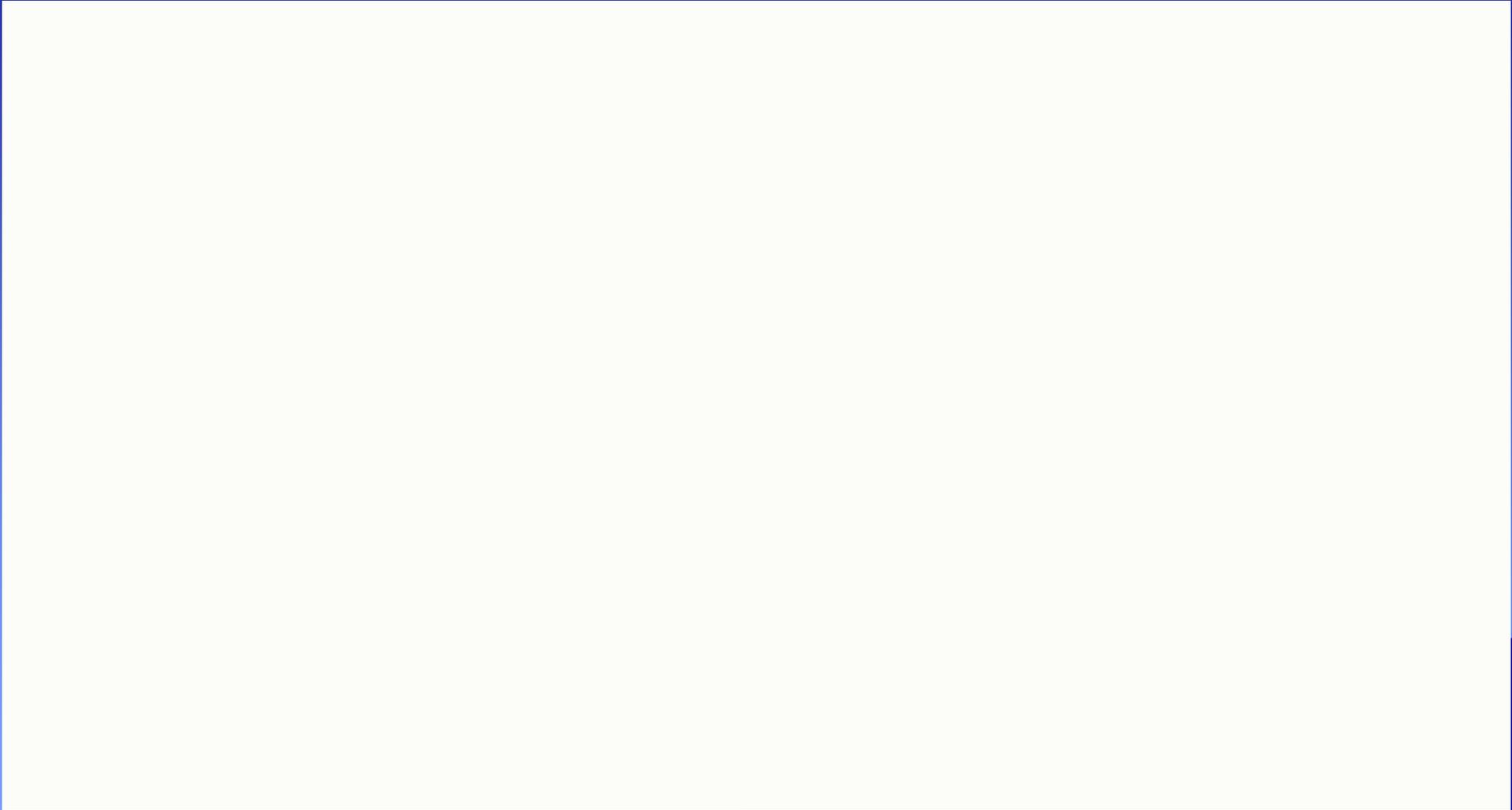
P_0

x

L

Figure 6 Double-slit interference can be used to determine the wavelength of light. Because L is much larger than d and the angle θ is small, the equation for the wavelength is simplified.

Double slit experiment

PART 2

7	Define a diffraction pattern	As mentioned in the textbook	204
8	Define a reflection grating and give examples.	As mentioned in the textbook	205
9	Derive the relation of the wavelength from double-slit investigation λ=xd/L where(x) is the distance on the screen from the central bright fringe to the first bright band, 'd' is the distance between the slits, and 'L' is the distance from the slits to the screen.	As mentioned in the textbook	195

Single-Slit Diffraction

When studying light, you learned that wavefronts of light diffract when they pass around an edge. Diffraction can be explained by using Huygens' principle that a wavefront is made up of many small point-source wavelets. When light passes through a slit that has two closely spaced edges, a pattern is produced on a screen. This pattern, called a **diffraction pattern**, results from constructive and destructive interference of Huygens' wavelets.
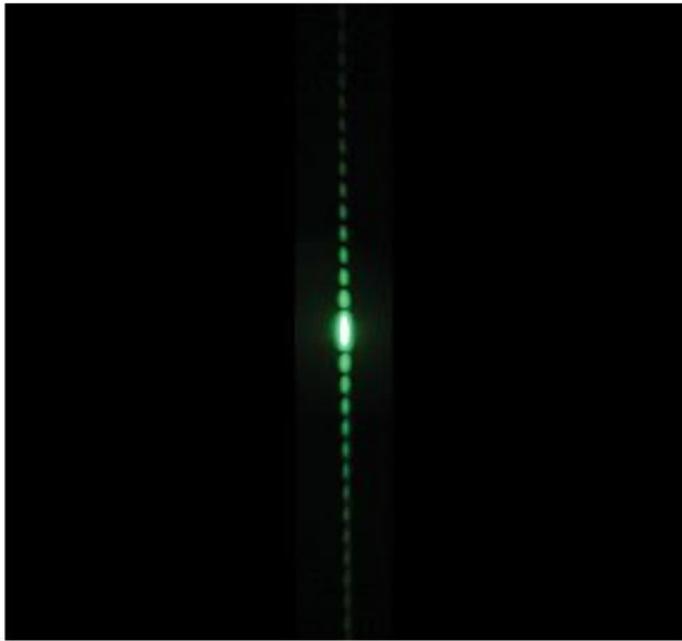
Green Light   **Red Light**   **White Light**

Reflection gratings

You might have seen that light that reflects off CDs, DVDs, or Blu-ray Discs (or optical discs) creates a spectrum diffraction pattern, as in **Figure 16.** A type of diffraction grating made by inscribing fine lines on metallic or reflective glass surfaces is called a reflection grating. Optical discs are examples of reflection gratings. If you were to shine monochromatic light on an optical disc, the reflected light would produce a reflection pattern on a screen. Transmission and reflection gratings produce similar patterns, which can be analyzed in the same manner.

The surfaces of optical discs are covered with lines of microscopic indentations called pits separated by flat areas called lands, as shown in **Figure 16,** arranged in a spiral. The turns of the spiral act as a diffraction grating, separating colors by interference. The fact that optical discs are diffraction gratings is not important to their function, but the way they interact with different wavelengths of light is important.
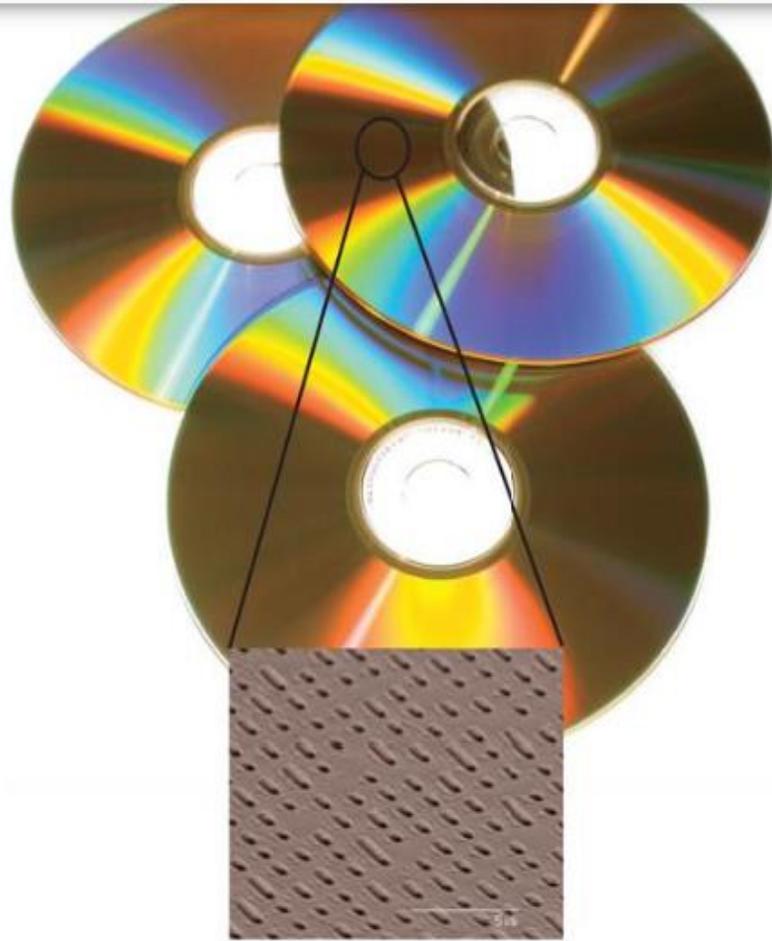

Figure 16 A CD is a reflection grating, producing a light spectrum. A magnified view of the surface of a CD shows the arrangement of pits and lands.

Interference of Coherent Light

The position of the bands depends on the wavelength of the light.

Wavelength from Double-Slit Investigation

$$l = \frac{xd}{L}$$

Double-Slit Interference Top View

Destructive interference ― ― ― ― ― ― ―

Constructive interference _____

Source

S_1

S_2

Screen

Dark
Bright
Dark
Bright
Dark
Bright
Dark
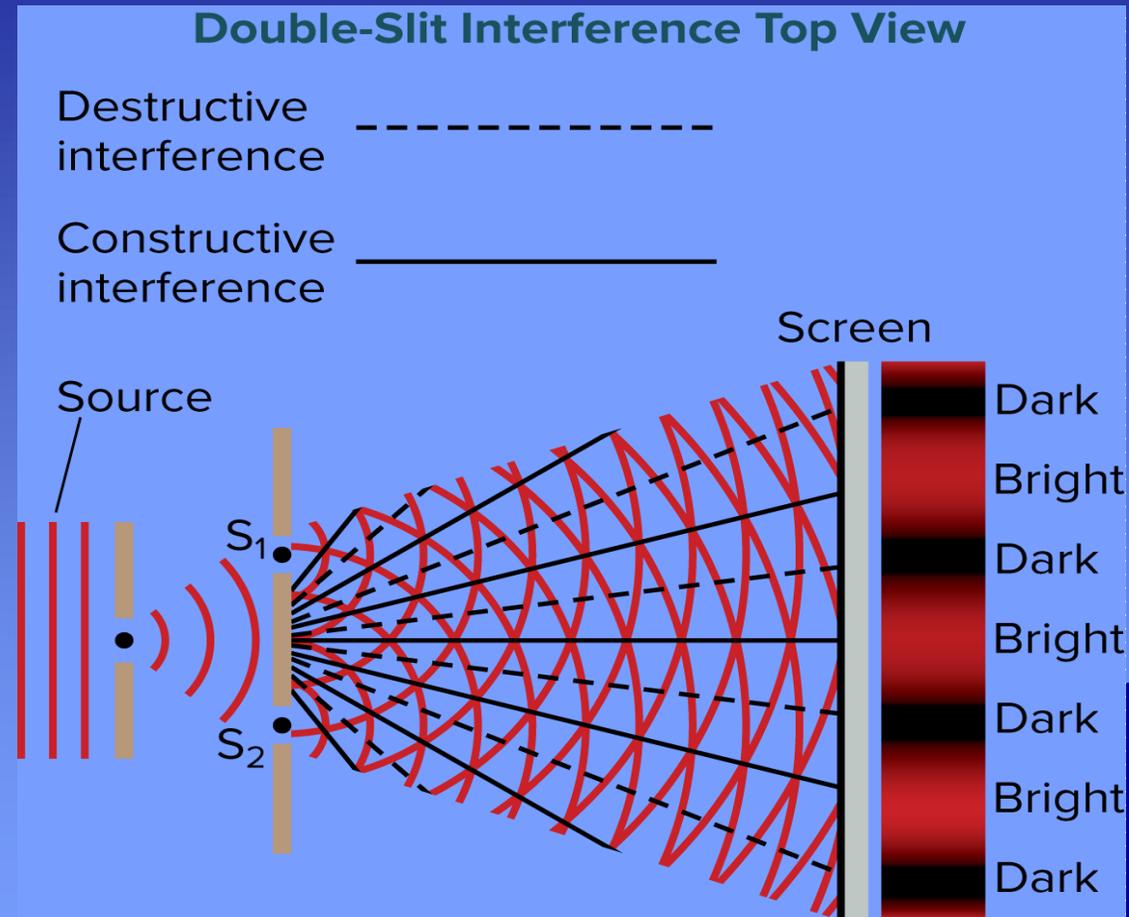
10	Differentiate between AM and FM signals.	As mentioned in the textbook	185
11	Calculate the speed of electromagnetic waves in different mediums of different dielectric constants.	Practice problems	181
12	Explain how transformers are used in the National Grid System to transmit power through long distances with minimal power losses.	As mentioned in the textbook	167
13	Define self-inductance and describe the effect produced by self induction in a circuit containing a coil when the current is switched on or off suddenly.	As mentioned in the textbook	163

S.No.	FM	AM
1.	Amplitude of FM wave is constant. It is independent of the modulation index.	Amplitude of AM wave will change with the modulating voltage.
2.	Hence, transmitted power remains constant. It is independent of m_f.	Transmitted power is dependent on the modulation index.
3.	All the transmitted power is useful.	Carrier power and one sideband power are useless.
4.	FM receivers are immune to noise.	AM receivers are not immune to noise.
5.	It is possible to decrease noise further by increasing deviation.	This feature is absent in AM.
6.	Bandwidth = $2[\Delta f + f_m]$. The bandwidth depends on modulation index.	BW = $2 f_m$. It is not dependent on the modulation index.
7.	BW is large. Hence, wide channel is required.	BW is much less than FM.

Practice Problems

42. What is the speed of an electromagnetic wave traveling through air? Use $c = 299{,}792{,}458$ m/s in your calculation.

$$v = \frac{c}{\sqrt{k}} = \frac{299{,}792{,}458 \text{ m/s}}{\sqrt{1.00054}}$$

$$= 2.99712 \times 10^8 \text{ m/s}$$

43. Water has a dielectric constant of 1.77. What is the speed of light in water?

$$v = \frac{c}{\sqrt{k}} = \frac{3.00 \times 10^8 \text{ m/s}}{\sqrt{1.77}}$$

$$= 2.25 \times 10^8 \text{ m/s}$$

44. The speed of light traveling through a material is 2.43×10^8 m/s. What is the dielectric constant of the material?

$$v = \frac{c}{\sqrt{k}}$$

$$k = \left(\frac{c}{v}\right)^2 = \left(\frac{3.00 \times 10^8 \text{ m/s}}{2.43 \times 10^8 \text{ m/s}}\right)^2 = 1.52$$

Everyday uses of transformers

Long-distance transmission of electrical energy is economical only if very high potential differences are used. High potential differences reduce the current required in the transmission lines, keeping the wasteful energy transformations low. As shown in **Figure 16,** step-up transformers are used at power sources, where they can develop potential differences up to $480{,}000$ V. When the energy reaches homes, step-down transformers reduce the potential difference to 120 V. Game systems, printers, laptop computers, and rechargeable toys have transformers inside their casings or in blocks attached to their cords. These small transformers further reduce potential differences from wall outlets to the 3 V–26 V range.

① Generator
Kinetic energy from wind spins turbines, which turn armatures in a magnetic field and induce an *EMF*. The *EMF* is converted to an electric current and sent to a substation.

② Substation
A step-up transformer in the substation increases the voltage for cost-effective transmission.

③ Step-Down Transformer
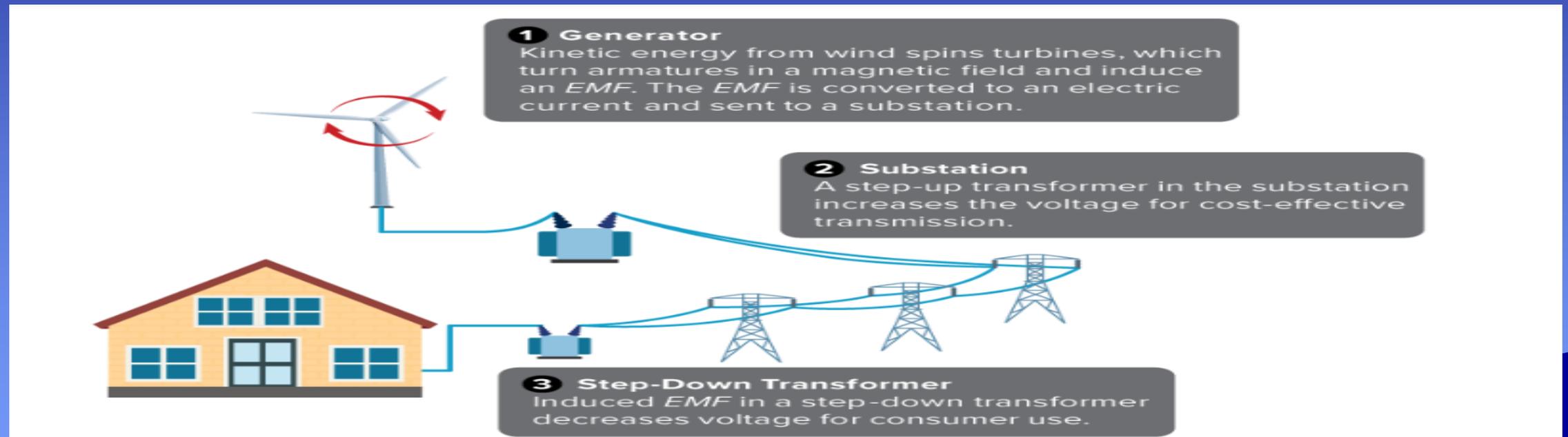Induced *EMF* in a step-down transformer decreases voltage for consumer use.

Figure 16 Step-up transformers increase potential differences (voltages) in overhead power lines. Step-down transformers decrease potential differences for consumer use.

Self-inductance

An *EMF* can be induced in a wire when the magnetic field in the region of the wire changes. The field can be external, or it can be generated by the current in the wire itself, as in **Figure 13.**
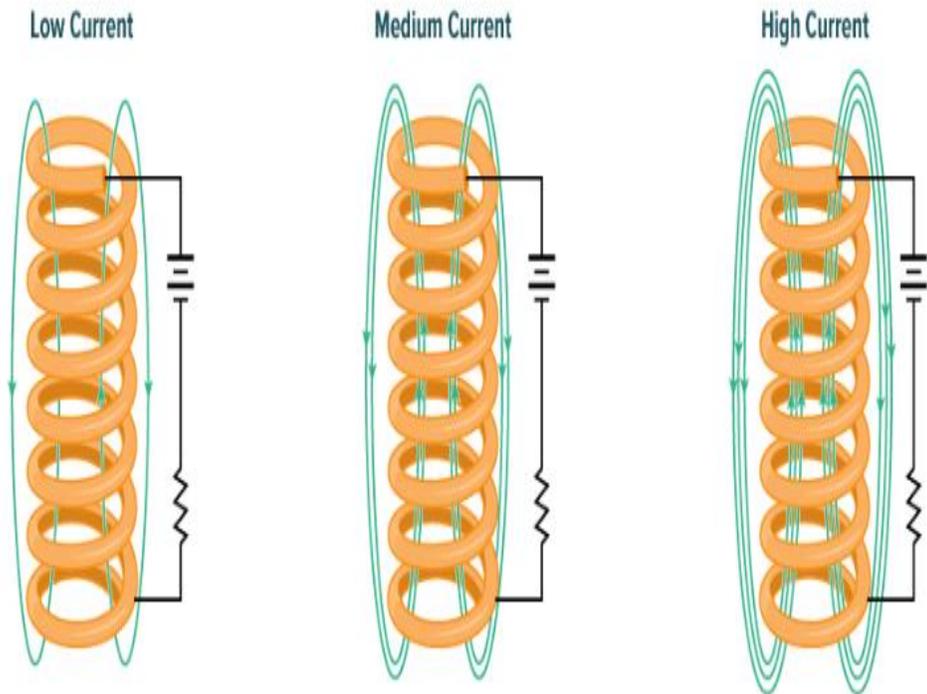
Low Current	Medium Current	High Current

Figure 13 As the current in the coil increases, the magnetic field generated by the current also increases. The increase in the magnetic field induces an EMF that opposes the direction of current, and more energy is needed to increase the current further.

14	Relate the effective current and effective potential difference to their maximum values in an AC circuit.	Practice problems	159
15	Describe some applications of the different types of electromagnetic waves.	As mentioned in the textbook	179
16	Apply the wave equation to calculate the wavelength, frequency, or speed of electromagnetic waves.	Practice problems	177

Alternating currents and generators There are two main types of generators. In direct current (DC) generators, charges move in a single direction, as they do in batteries. Current is in one direction because the wires of the armature connect to a circuit by means of a commutator.

In contrast, alternating current (AC) generators use a slip-ring device to connect wires to a circuit. In this device, one ring is connected to one end of the armature, and the other ring is connected to the other end of the armature, as shown in the left of **Figure 8**. As the armature rotates through 180°, the induced *EMF* reverses direction. This means the current also reverses direction. The current alternates from positive to negative. In a consistently turned generator, the current alternates at a fixed rate and varies sinusoidally, as shown in the top graph of **Figure 8**.

The frequency of alternating current is different in different countries. Electricity in United Arab Emirates is 220 Volts, alternating at 50 cycles per second. If you travel to United Arab Emirates with a device that does not accept 220 Volts at 50 Hertz, you will need a voltage converter.

Average power The power produced by an AC generator is the product of the current and the potential difference. Because both current and potential difference vary, the power in the circuit varies. The graph at the bottom right of **Figure 8** shows the power versus time produced by an AC generator. Note that power is always positive because I and V are either both positive or both negative. Average power, P_{AC}, is half the maximum power; thus, $P_{AC} = \frac{1}{2} P_{AC\ max}$.

Effective current It is common to describe alternating current and potential difference in terms of effective current and effective potential difference, rather than referring to their maximum values. Recall that $P = I^2R$. Thus, effective current (I_{eff}) can be expressed in terms of the average AC power, as $P_{AC} = I_{eff}^2R$. To determine I_{eff} in terms of maximum current (I_{max}), start with the power relationship, $P_{AC} = \frac{1}{2} P_{AC\ max}$, and substitute in I^2R. Then solve for I_{eff}.

EFFECTIVE CURRENT

Effective current is equal to $\frac{\sqrt{2}}{2}$ times the maximum current.

$$I_{eff} = \left(\frac{\sqrt{2}}{2}\right) I_{max} = 0.707 I_{max}$$

Effective potential difference Similarly, because $P = \frac{V^2}{R}$, the effective potential difference is given by the following equation.

EFFECTIVE POTENTIAL DIFFERENCE

Effective potential difference is equal to $\frac{\sqrt{2}}{2}$ times the maximum potential difference.

$$V_{eff} = \left(\frac{\sqrt{2}}{2}\right) V_{max} = 0.707 V_{max}$$

Effective potential difference is commonly referred to as RMS (root mean square) potential difference. In the United States, the RMS potential difference generally available at wall outlets is described as 120 V, where 120 V is the magnitude of the effective potential difference, not the maximum potential difference. In many other countries, the RMS potential difference is 240 V.

5. A generator develops a maximum potential difference of 170 V.

a. What is the effective potential difference?

b. A 60 W lamp is placed across the generator with an I_{max} of 0.70. What is the effective current through the lamp?

c. What is the resistance of the lamp when it is working?

SOLUTION:

a.

$V_{eff} = (0.707)V_{max} = (0.707)(170 \text{ V})$

$= 120 \text{ V}$

b.

$I_{eff} = (0.707)I_{max} = (0.707)(0.70 \text{ A})$

$= 0.49 \text{ A}$

c.

$R = \dfrac{V_{eff}}{I_{eff}} = \dfrac{\dfrac{V_{max}}{\sqrt{2}}}{\dfrac{I_{max}}{\sqrt{2}}} = \dfrac{V_{max}}{I_{max}} = \dfrac{170 \text{ V}}{0.70 \text{ A}}$

$= 2.4 \times 10^2 \ \Omega$

6. The RMS potential difference of an AC household outlet is 117 V. What is the maximum potential difference across a lamp connected to the outlet? If the RMS current through the lamp is 5.5 A, what is the lamp's maximum current?

SOLUTION:

$V_{max} = \dfrac{V_{eff}}{0.707} = \dfrac{117 \text{ V}}{0.707} = 165 \text{ V}$

$I_{max} = \dfrac{I_{eff}}{0.707} = \dfrac{5.5 \text{ A}}{0.707} = 7.8 \text{ A}$

7. If the average power used over time by an electric light is 75 W, what is the peak power?

SOLUTION:

$P = \dfrac{1}{2}P_{max}$

$P_{max} = (2)P = (2)(75 \text{ W}) = 1.5 \times 10^2 \text{ W}$

Jam campus

Describe some applications of the different types of electromagnetic waves.

Uses of lower-frequency waves

Radio waves The lowest-frequency waves, radio waves, are used mainly to broadcast information. Radio waves with long wavelengths can be transmitted long distances because they reflect off ions in the atmosphere. Shorter radio waves used for FM radio and television travel in straight paths and so must be relayed from station to station across Earth's curved surface.

Microwaves Cellular phones and the Global Positioning System transmit information using very-short-wavelength radio waves called microwaves. You also use microwaves to cook food. The water and fat in food absorb microwaves, and the waves' energy turns to thermal energy to cook the food.

Infrared waves Cameras with infrared sensors can produce images, and infrared night-vision goggles and cameras allow people to see in the dark. Because hot objects emit far infrared waves (with long wavelengths), infrared detectors can measure the temperature of buildings and other objects. Near infrared radiation (with shorter wavelengths and higher frequencies) can carry signals on optical fiber systems or through the air, programmed from remote-control devices.
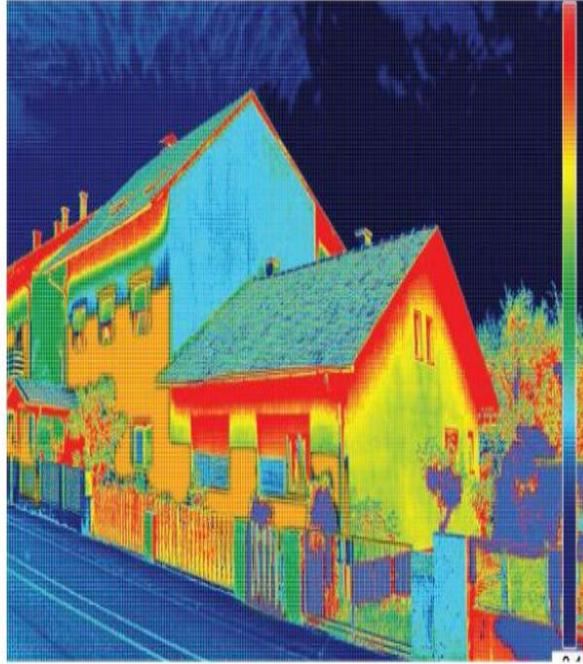

UV radiation With higher frequencies than infrared waves, ultraviolet (UV) radiation can ionize molecules and atoms and cause chemical reactions, resulting in harmful effects such as sunburn. UV radiation also is used in industry to cure polymers and sterilize instruments. In the semiconductor industry, UV radiation is used to etch patterns on silicon wafers in integrated circuits. UV radiation can also be used to reveal forensic evidence.

Uses of higher-frequency waves

X-rays X-rays are produced when high-energy electrons rip tightly bound electrons off atoms. When the electrons in the atoms rearrange themselves, they emit X-rays. German physicist William Roentgen discovered X-rays in 1895 using a vacuum glass tube. You are familiar with X-ray pictures of bones and teeth. X-rays are also widely used to kill cancerous cells.
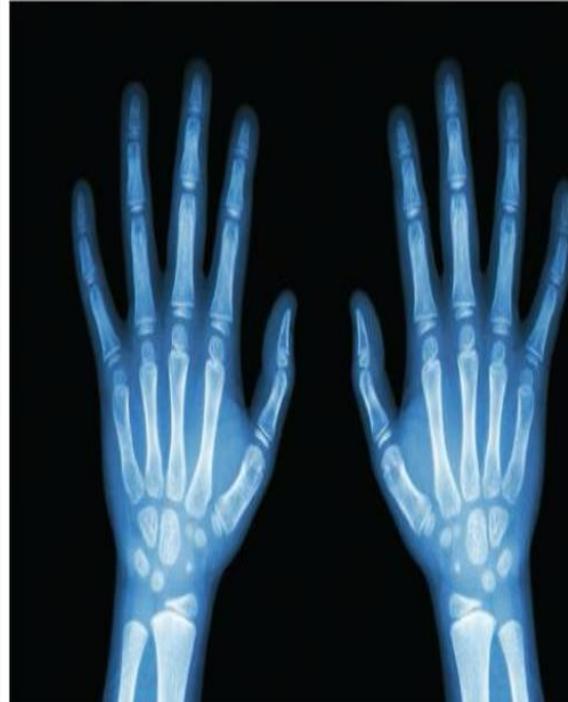
Gamma rays High-frequency gamma rays come from the radioactive nuclei of atoms. Gamma rays can be used to detect dangerous substances in shipping containers. In medicine, they are used to treat cancer by destroying cells.

Apply the wave equation to calculate the wavelength, frequency, or speed of electromagnetic waves PRBLS 38-41

38. What is the wavelength of green light that has a frequency of 5.70×10^{14} Hz?

$$\lambda = \frac{c}{f} = \frac{3.00 \times 10^8 \text{ m/s}}{5.70 \times 10^{14} \text{ Hz}} = 5.26 \times 10^{-7} \text{ m}$$

39. An electromagnetic wave has a frequency of 8.2×0^{14} Hz. What is the wavelength of the wave?

$$\lambda = \frac{c}{f} = \frac{3.00 \times 10^8 \text{ m/s}}{8.2 \times 10^{14} \text{ Hz}} = 3.7 \times 10^{-7} \text{ m}$$

40. What is the frequency of an electromagnetic wave that has a wavelength of 2.2×10^{-2} m?

$$\lambda = \frac{c}{f}$$

$$f = \frac{c}{\lambda} = \frac{3.00 \times 10^{8} \text{ m/s}}{2.2 \times 10^{-2} \text{ m}} = 1.4 \times 10^{10} \text{ Hz}$$

41. **CHALLENGE** If an electromagnetic wave is propagating to the right and the electric field is in and out of the page, in what direction is the magnetic field?

up and down

PART 3

17	Apply the equation F=BILSin(Θ)to calculate the magnitude of the force on a straight segment of a current-carrying wire placed in a uniform magnetic field.	EXAMPLE 1 Practice problems	154-155
18	Calculate the maximum and effective values of current, voltage, and power for an AC generator.	Practice problems	159
19	Apply the ideal transformer equation to solve numerical problems.	EXAMPLE 2 Practice problems	166
20	Apply the relation (λ=Xd/L) to calculate the wavelength or to find an unknown distance in a double-slit investigation given the other values.	EXAMPLE 1 Practice problems	196
21	غير معلن	غير معلن	غير معلن
22	غير معلن	غير معلن	غير معلن

1. You move a straight wire that is 0.5 m long at a speed of 20 m/s vertically through a 0.4 T magnetic field pointed in the horizontal direction.

a. What *EMF* is induced in the wire?

b. The wire is part of a circuit with a total resistance of 6.0 Ω. What is the current?

2. A straight wire that is 25 m long is mounted on an airplane flying at 125 m/s. The wire moves in a perpendicular direction through Earth's magnetic field ($B = 5.0 \times 10^{-5}$ T). What *EMF* is induced in the wire?

3. A straight wire segment in a circuit is 30.0 m long and moves at 2.0 m/s perpendicular to a magnetic field.

a. A 6.0 V *EMF* is induced. What is the magnetic field?

b. The total resistance of the circuit is 5.0 Ω. What is the current?

SOLUTION: 1

a. $EMF = BLv(\sin \theta)$
   $= (0.4 \text{ T})(0.5 \text{ m})(20 \text{ m/s})(1)$
   $= 4 \text{ V}$

b.
$I = \dfrac{EMF}{R} = \dfrac{4 \text{ V}}{6.0 \text{ } \Omega} = 0.7 \text{ A}$

SOLUTION: 2

$EMF = BLv(\sin \theta)$

$= (5.0 \times 10^{-5} \text{ T})(25 \text{ m})(125 \text{ m/s})(1)$

$= 0.16 \text{ V}$

SOLUTION: 3

a. $EMF = BLv(\sin \theta)$
   $6.0 \text{ V} = B(30.0 \text{ m})(2.0 \text{ m/s})(1)$
   $B = 0.10 \text{ T}$

b.
$I = \dfrac{EMF}{R} = \dfrac{6.0 \text{ V}}{5.0 \text{ } \Omega} = 1.2 \text{ A}$

5. A generator develops a maximum potential difference of 170 V.

a. What is the effective potential difference?

b. A 60 W lamp is placed across the generator with an I_{max} of 0.70. What is the effective current through the lamp?

c. What is the resistance of the lamp when it is working?

SOLUTION:

a.
$$V_{eff} = (0.707)V_{max} = (0.707)(170 \text{ V})$$
$$= 120 \text{ V}$$

b.
$$I_{eff} = (0.707)I_{max} = (0.707)(0.70 \text{ A})$$
$$= 0.49 \text{ A}$$

c.
$$R = \frac{V_{eff}}{I_{eff}} = \frac{\dfrac{V_{max}}{\sqrt{2}}}{\dfrac{I_{max}}{\sqrt{2}}} = \frac{V_{max}}{I_{max}} = \frac{170 \text{ V}}{0.70 \text{ A}}$$
$$= 2.4 \times 10^2 \text{ }\Omega$$

6. The RMS potential difference of an AC household outlet is 117 V. What is the maximum potential difference across a lamp connected to the outlet? If the RMS current through the lamp is 5.5 A, what is the lamp's maximum current?

SOLUTION:
$$V_{max} = \frac{V_{eff}}{0.707} = \frac{117 \text{ V}}{0.707} = 165 \text{ V}$$

$$I_{max} = \frac{I_{eff}}{0.707} = \frac{5.5 \text{ A}}{0.707} = 7.8 \text{ A}$$

7. If the average power used over time by an electric light is 75 W, what is the peak power?

SOLUTION:
$$P = \frac{1}{2}P_{max}$$

$$P_{max} = (2)P = (2)(75 \text{ W}) = 1.5 \times 10^2 \text{ W}$$

The ideal transformer In an ideal transformer, the electrical power delivered to the secondary circuit equals the power supplied to the primary circuit. An ideal transformer dissipates no power itself. Because it is 100 percent efficient, it can be represented by the following equations:

$$P_P = P_s$$
$$V_P I_P = V_s I_s$$

Rearranging the equation to find the ratio $\dfrac{V_P}{V_s}$ shows that the current in the primary circuit depends on how much current is required by the secondary circuit. This relationship can be combined with the relationship shown earlier (between potential difference and the number of turns) to result in the following equation.

TRANSFORMER EQUATION
The ratio of the current in the secondary coil to the current in the primary coil is equal to the ratio of the potential difference in the primary coil to the potential difference in the secondary coil, which is also equal to the ratio of the number of turns on the primary coil to the number of turns on the secondary coil.

$$\frac{I_s}{I_p} = \frac{V_p}{V_s} = \frac{N_p}{N_s}$$

EXAMPLE 2

STEP-UP TRANSFORMERS A step-up transformer has a primary coil consisting of 200 turns and a secondary coil consisting of 3000 turns. The primary coil is supplied with an effective AC potential difference of 90.0 V.
a. What is the potential difference in the secondary circuit?
b. The current in the secondary circuit is 2.0 A. What is the current in the primary circuit?

1 ANALYZE AND SKETCH THE PROBLEM

- Draw an iron core that has turns of wire on either side.

- Label the variables I, V, and N.
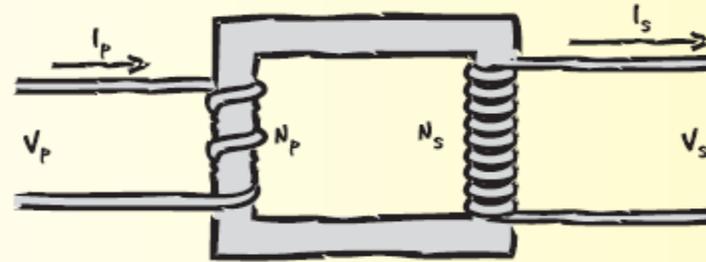
KNOWN		UNKNOWN
$N_P = 200$	$V_P = 90.0$ V	$V_s = ?$
$N_s = 3000$	$I_s = 2.0$ A	$I_p = ?$

2 SOLVE FOR THE UNKNOWN

a. Solve for V_s.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$V_s = \frac{N_s V_p}{N_p}$$

$$V_s = \frac{N_s V_p}{N_p}$$

$$= \frac{(3000)(90.0 \text{ V})}{200} \qquad \blacktriangleleft \text{ Substitute } N_s = 3000, V_p = 90.0 \text{ V}, N_p = 200.$$

$$= 1350 \text{ V}$$

b. The power in the primary and secondary circuits is equal assuming 100 percent efficiency.

$$P_p = P_s$$

$$V_p I_p = V_s I_s \qquad \blacktriangleleft \text{ Substitute } P_p = V_p I_p, P_s = V_s I_s.$$

Solve for I_p.

$$I_p = \frac{V_s I_s}{V_p}$$

$$= \frac{(1350 \text{ V})(2.0 \text{ A})}{90.0 \text{ V}} \qquad \blacktriangleleft \text{ Substitute } V_s = 1350 \text{ V}, I_s = 2.0 \text{ A}, V_p = 90.0 \text{ V}.$$

$$= 3.0 \times 10^1 \text{ A}$$

16. A step-down transformer has 7500 turns on its primary coil and 125 turns on its secondary coil. The potential difference across the primary circuit is 7.2 kV. What is the potential difference across the secondary circuit? If the current in the secondary circuit is 36 A, what is the current in the primary circuit?

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$V_s = \frac{V_p N_s}{N_p} = \frac{(7.2 \times 10^3 \text{ V})(125)}{7500}$$

$$= 1.2 \times 10^2 \text{ V}$$

$$V_p I_p = V_s I_s$$

$$I_p = \frac{V_s I_s}{V_p} = \frac{(1.2 \times 10^2 \text{ V})(36 \text{ A})}{7.2 \times 10^3 \text{ V}} = 0.60 \text{ A}$$

17. → **CHALLENGE** A step-up transformer that is 95 percent efficient has 300 turns on its primary coil and 90,000 turns on its secondary coil. The potential difference of the generator to which the primary circuit is attached is 60.0 V. What is the potential difference across the secondary circuit? The current in the secondary circuit is 0.50 A. What current is in the primary circuit? ¶

$$V_s = \frac{V_p N_s}{N_p} = \frac{(60.0 \text{ V})(90,000)}{300}$$ ¶

$$= 1.80 \times 10^4 \text{ V}$$

$$P_s = V_s I_s = (1.80 \times 10^4 \text{ V})(0.50 \text{ A})$$

$$= 9.0 \text{ kW}$$

$$P_p = \frac{9.0 \text{ kW}}{0.95} = 9.47 \text{ kW}$$ ¶

$$I_p = \frac{P_p}{V_p} = \frac{9.47 \text{ kW}}{60.0 \text{ V}} = 1.6 \times 10^{-1} \text{ A}$$

Transformers

Step-Up Transformer

Primary | Secondary

10.0 A
5 turns
2.5 A
100 V
400 V
20 turns
1000 W
1000 W
Core

Step-Down Transformer

Primary | Secondary

2.0 A
50 turns
10.0 A
1000 V
200 V
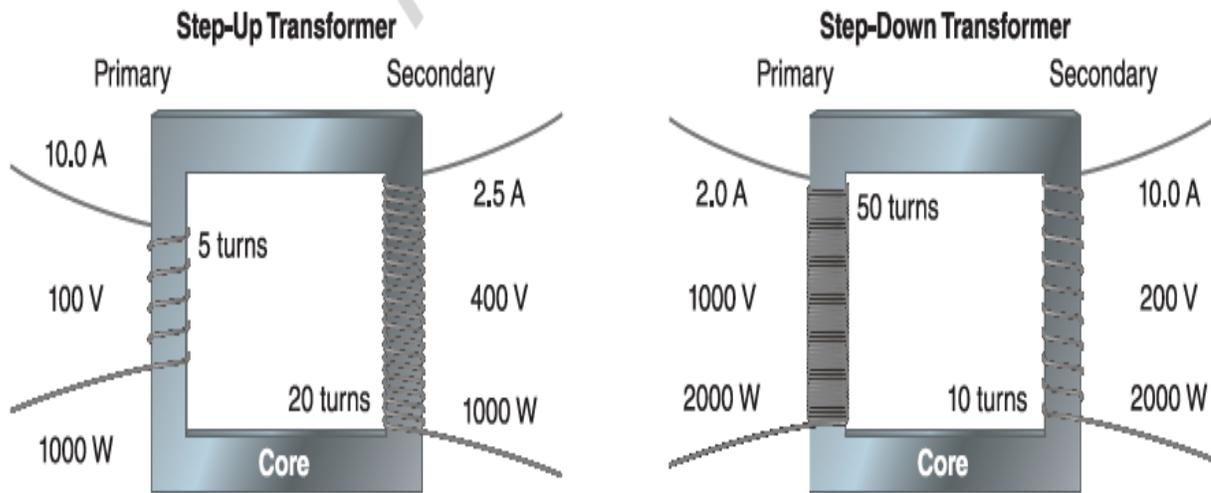2000 W
10 turns
2000 W
Core

Figure 15 The ratio of primary potential difference to secondary potential difference in a transformer depends on the ratio of the number of turns on the primary coil to the number of turns on the secondary coil. Secondary potential difference can be greater than the primary (left) or less than the primary (right).

$$\frac{\text{primary potential difference}}{\text{secondary potential difference}} = \frac{\text{number of turns in primary coil}}{\text{number of turns in secondary coil}}$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

If the secondary potential difference is larger than the primary potential difference, as it is in the left part of **Figure 15**, the transformer is called a **step-up transformer**. If the secondary potential difference is smaller than the primary potential difference, as in the right part of **Figure 15**, the transformer is called a **step-down transformer**.

☑ READING CHECK **Compare** How do step-up transformers differ from step-down transformers?

Transformers

You have probably seen metal cylinders attached to utility poles, such as the cylinder on the pole in **Figure 14.** Inside each of these cylinders is a transformer. **Transformers** are devices that increase or decrease potential differences with relatively little waste of energy. Only alternating current (AC) can be sent through a transformer. Direct current (DC) cannot pass through a transformer.

How transformers work You read that self-inductance produces an *EMF* when current changes in a single coil. A transformer has two coils, electrically insulated from each other but wound around the same iron core, as you can see in **Figure 15.** When one coil–the primary coil–is connected to an AC source, the changing current creates a changing magnetic field that is carried through the core to the other coil–the secondary coil. In the secondary coil, the changing magnetic field induces a varying *EMF* and current. An *EMF* and current in one coil due to changing current in another coil is called **mutual inductance.**

The *EMF* induced in the secondary coil, called the secondary potential difference, is proportional to the potential difference provided to the primary coil. The secondary potential difference also depends on what is called the turns ratio. The turns ratio is the number of turns of wire in the secondary coil divided by the number of turns in the primary coil, as shown on the right in the following expressions.

$$\frac{\text{primary potential difference}}{\text{secondary potential difference}} = \frac{\text{number of turns in primary coil}}{\text{number of turns in secondary coil}}$$

$$\frac{V_P}{V_s} = \frac{N_P}{N_s}$$

If the secondary potential difference is larger than the primary potential difference, as it is in the left part of **Figure 15,** the transformer is called a **step-up transformer.** If the secondary potential difference is smaller than the primary potential difference, as in the right part of **Figure 15,** the transformer is called a **step-down transformer.**

☑ READING CHECK Compare How do step-up transformers differ from step-down transformers?

6.12 Relate the turns ratio of a transformer to its current and its
**voltage ratio and apply the coresponding
equation in problem solving.**
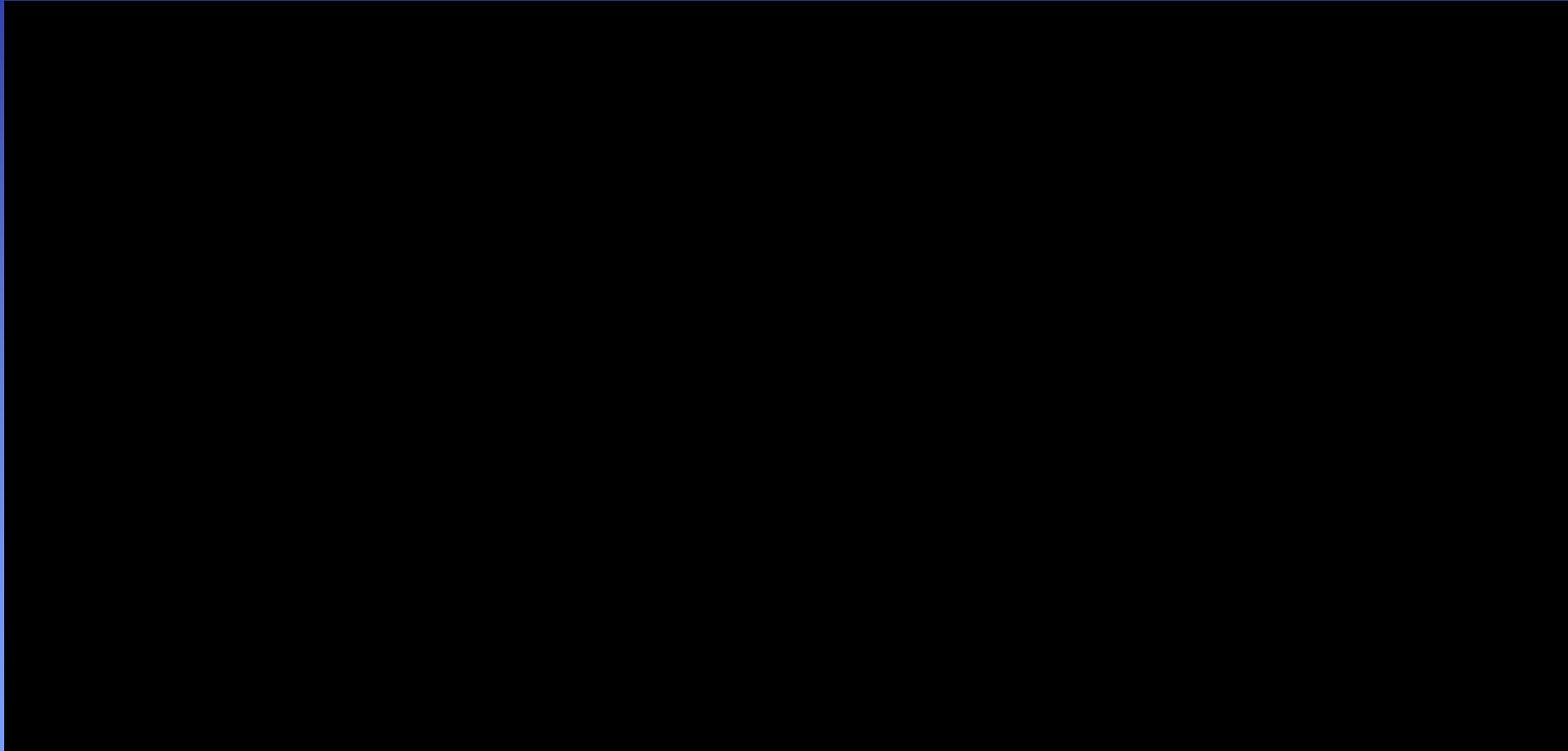
1. Violet light falls on two slits separated by 1.90×10^{-5} m. A first-order bright band appears 13.2 mm from the central bright band on a screen 0.600 m from the slits. What is λ?

$$\lambda = \frac{xd}{L}$$

$$= \frac{(13.2 \times 10^{-3} \text{ m})(1.90 \times 10^{-5} \text{ m})}{0.600 \text{ m}}$$

$$= 418 \text{ nm}$$

2. Yellow-orange light of wavelength 596 nm from a sodium lamp is aimed at two slits that are separated by 1.90×10^{-5} m. What is the distance from the central band to the first-order yellow band if the screen is 0.600 m from the slits?

$$x = \frac{\lambda L}{d}$$

$$= \frac{(596 \times 10^{-9} \text{ m})(0.600 \text{ m})}{1.90 \times 10^{-5} \text{ m}}$$

$$= 1.88 \times 10^{-2} \text{ m} = 18.8 \text{ mm}$$

3. In a double-slit investigation, physics students use a laser with $\lambda = 632.8$ nm. A student places the screen 1.000 m from the slits and finds the first-order bright band 65.5 mm from the central line. What is the slit separation?

$$\lambda = \frac{xd}{L}$$

$$d = \frac{\lambda L}{x}$$

$$= \frac{(632.8 \times 10^{-9} \text{ m})(1.000 \text{ m})}{65.5 \times 10^{-3} \text{ m}}$$

$$= 9.66 \times 10^{-6} \text{ m} = 9.66 \ \mu\text{m}$$

4. CHALLENGE Yellow-orange light with a wavelength of 596 nm passes through two slits that are separated by 2.25×10^{-5} m and makes an interference pattern on a screen. If the distance from the central line to the first-order yellow band is 2.00×10^{-2} m, how far is the screen from the slits?

$$\lambda = \frac{xd}{L}$$

$$L = \frac{xd}{\lambda}$$

$$= \frac{(2.00 \times 10^{-2} \text{ m})(2.25 \times 10^{-5} \text{ m})}{596 \times 10^{-9} \text{ m}}$$

$$= 0.755 \text{ m}$$

Lenz's law says that the magnetic field produced by the induced current is in the direction that is opposite the original field

Figure 9 A wire pulled through a magnetic field generates an *EMF*. The *EMF* produces a current in the circuit (*I*). Motion of the charges in the wire produces a force (*F*). The current also produces a magnetic field (blue dots and crosses) that, within the circuit, is in the direction opposite that of the field whose change caused it.

$EMF = BLv$

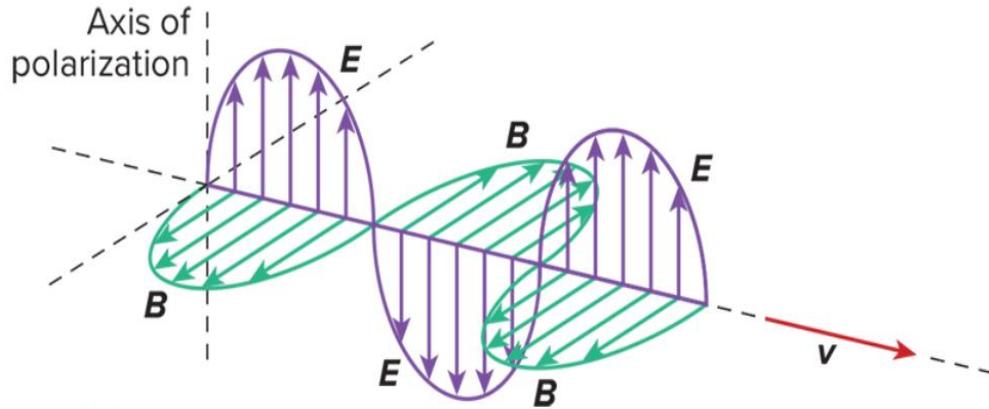$B_{out\ of\ page}$

L

$F = BIL$

I

v
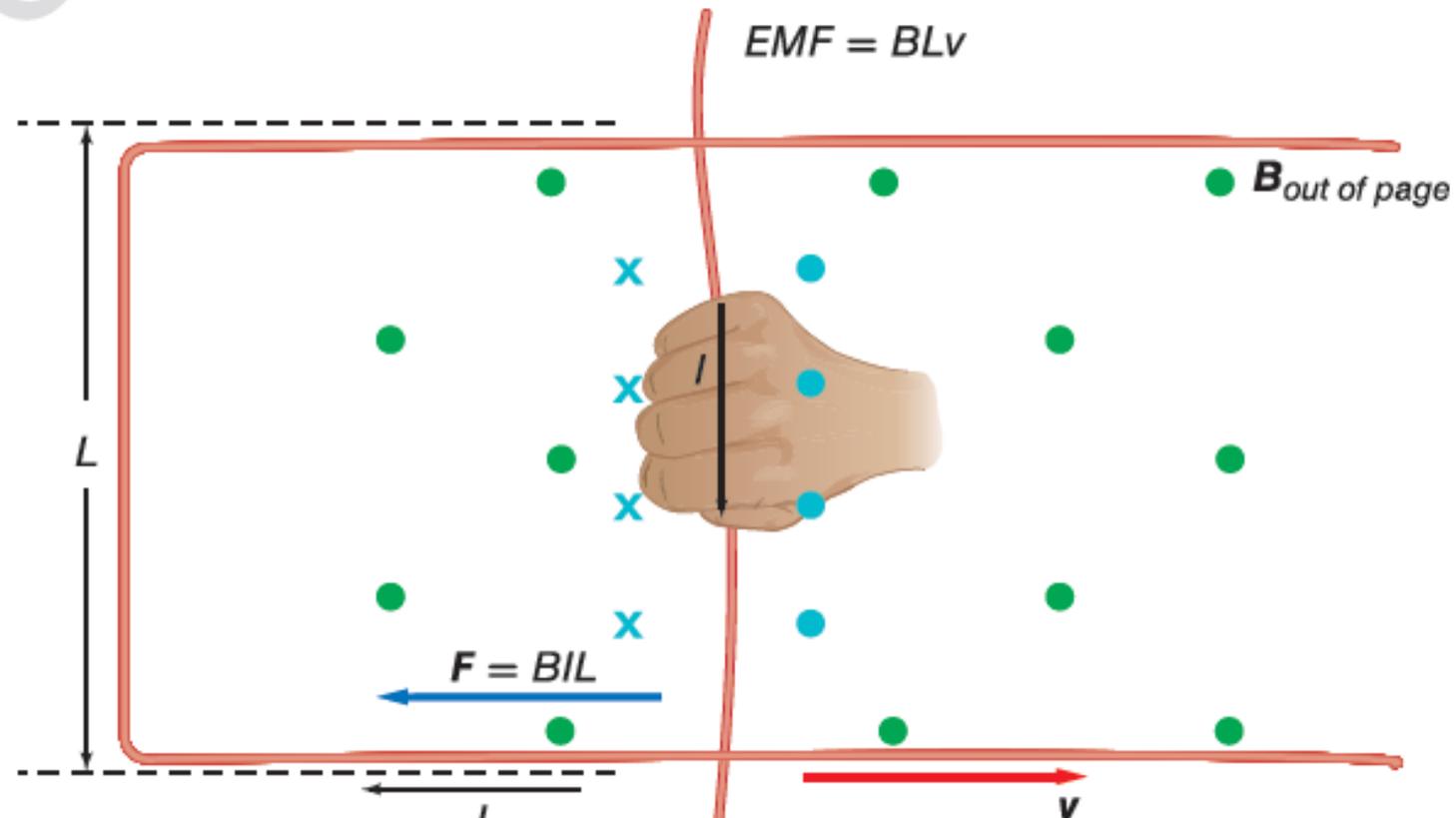
Figure 22 The electric and magnetic fields that make up an electromagnetic wave oscillate at right angles to each other and to the direction of the wave's velocity (v).

Definition: Electromagnetic waves or EM waves are **waves that are created as a result of vibrations between an electric field and a magnetic field**. In other words, EM waves are composed of oscillating magnetic and electric fields.

Electromagnetic Waves

A. Characteristics

1. Transverse wave that transfers electric and magnetic energy

2. Created when charged particles move

3. Produces energy called **electromagnetic radiation**

4. Travel at the speed of light – about 300,000 km/s
   a. Would go around the earth about 7.5x in a second
   b. Sunlight to reach Earth – about 8 minutes

5. All TRAVEL at the SAME speed

Explain what factors affect an antenna's sensitivity to electromagnetic waves of given wavelengths

Wire antennas

When an antenna is one-half the length of the wave it is designed to detect, the potential difference across its terminals is largest and the antenna is most efficient. Therefore, an antenna designed to receive radio waves is longer than one designed to receive microwaves.

Though antennas that are one-half wavelength long are most efficient, antennas that are one-quarter wavelength long are often used when the connection between the antenna and receiver is at the end rather than the middle of the antenna. Antennas can be made shorter by constructing them from a helical coil or by adding a dielectric material, such as a ceramic, with a dielectric coefficient higher than air.

Cell phones have as many as seven antennas. These phones typically communicate at frequencies near 850, 1700, 1900, and 2100 MHz. Further, they receive GPS signals at 1.575 GHz. They send and receive remote earpiece and WiFi signals at 2.4 GHz. Cell phone antennas built on ceramic dielectric blocks using printed conductors are typically only a few millimeters long. Laptop computers also have several antennas to accommodate WiFi and remote devices.
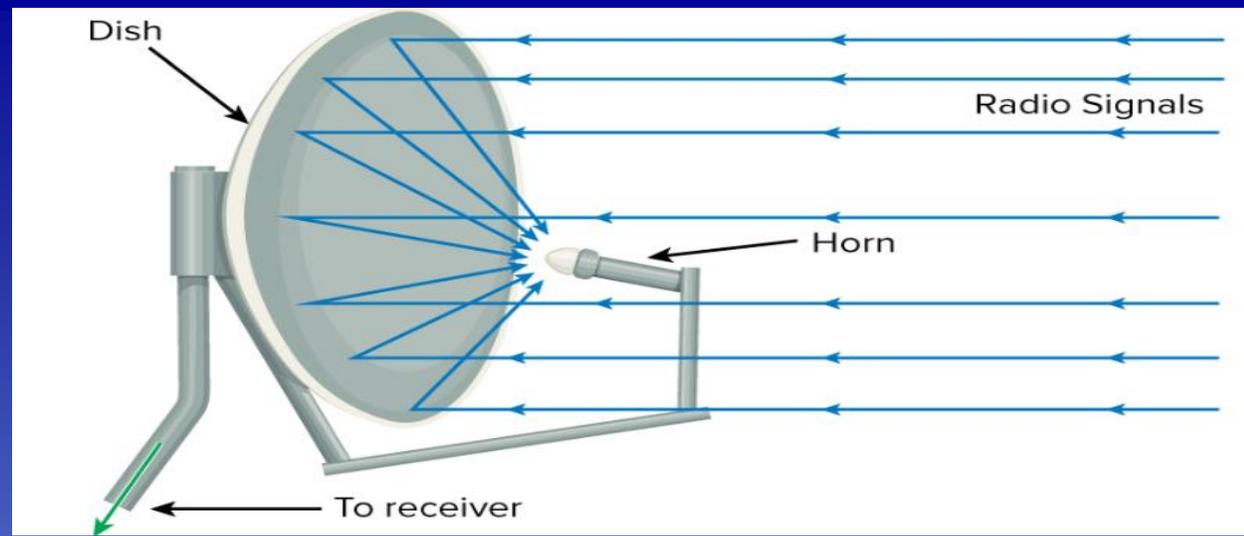
Figure 30 A received signal is reflected off the surface of a dish and focused into the horn, which contains the antenna. The large surface area of the dish collects more electromagnetic wave energy than a wire antenna does, making it well suited for receiving weak radio signals.
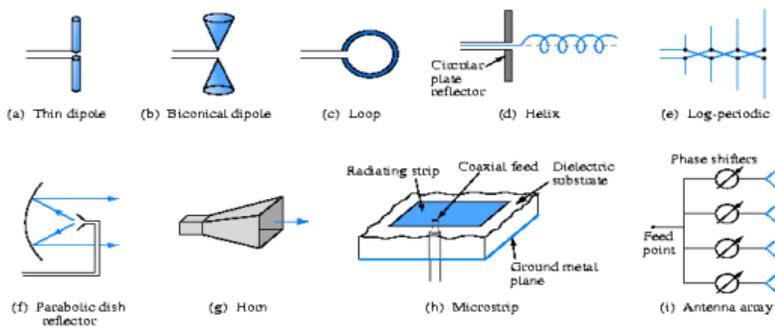
Dish antennas

All electromagnetic waves, not just light waves, undergo reflection, refraction, and diffraction. Dish antennas, such as the one in **Figure 30,** reflect short-wavelength radio signals, just as parabolic mirrors reflect light waves. A parabolic dish antenna reflects and focuses signals off its surface and into a horn. The horn, supported by a tripod structure over the main dish, contains a short dipole antenna. Like a telescope that shows only a narrow portion of sky, a dish antenna is sensitive only to signals coming from specific directions.
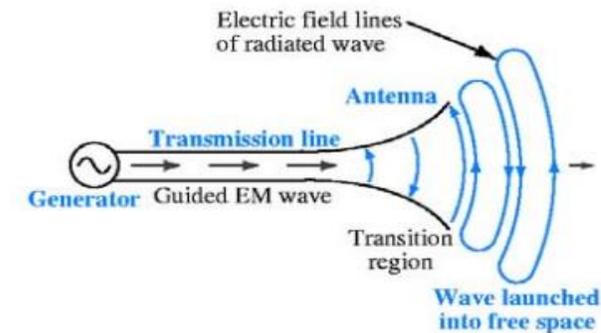
Antenna physical characteristics

- The antenna's size and shape largely determines the frequencies it can handle and how it radiates electromagnetic waves.

(a) Thin dipole (b) Biconical dipole (c) Loop (d) Helix (e) Log-periodic

(f) Parabolic dish reflector (g) Horn (h) Microstrip (i) Antenna array

Antennas

- An **antenna** is a device that provides a transition between guided electromagnetic waves in wires and electromagnetic waves in free space.

Electric field lines of radiated wave

Antenna

Transmission line

Generator   Guided EM wave

Transition region

Wave launched into free space

Explain how EM waves are received

Receiving Electromagnetic Waves

Antennas propagate electromagnetic waves into space. Antennas also capture electromagnetic waves, converting the waves' oscillating electric fields back to potential differences. As shown in **Figure 29,** a wave's electric field accelerates electrons in the metal of an antenna. The acceleration is largest when the antenna is positioned in the same direction as the wave polarization; that is, when it is parallel to the direction of the wave's electric field. A potential difference across the antenna's terminals oscillates at the frequency of the wave.
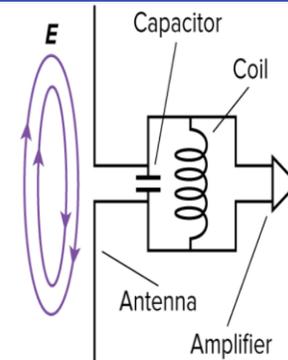

Figure 29 The changing electric fields from a radio station signal cause electrons in an antenna to accelerate. The information carried by the signal can then be decoded and amplified and used to drive a loudspeaker.