The Project Physics Course

Unit 4 Transparencies

Light and Electromagnetism

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Transparencies

UNIT 4
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Published by HOLT, RINEHART and WINSTON, Inc. New York, Toronto

Project Physics

Overhead Projection Transparencies

Unit 4

The Speed of Light

The Speed of Light

This transparency presents a greatly simplified visualization of how the speed of light can be found from the celestial observations of Römer and from Michelson's rotating mirror apparatus.

Römer's Celestial Method

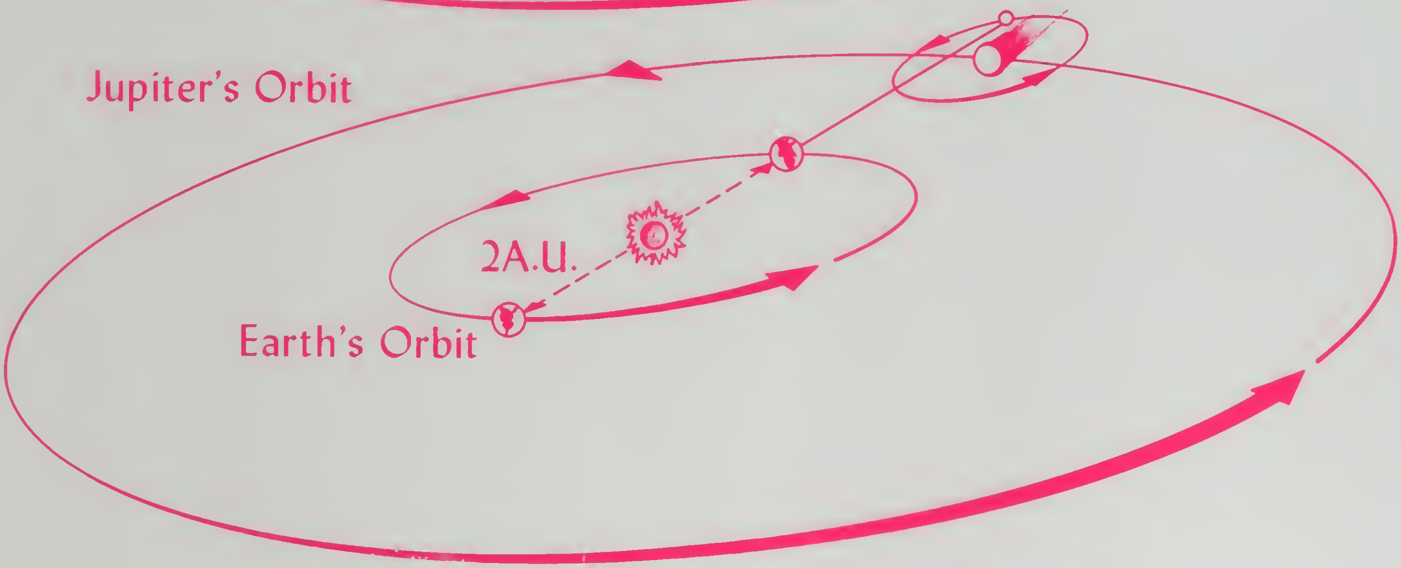
Overlay A — As Jupiter's innermost moon enters Jupiter's shadow it is no longer visible from the earth. The period of this moon was found to be 42.5 hours, i.e., it entered eclipse behind Jupiter or emerged from eclipse every 42.5 hours. However, monthly measurements indicated great variations in this schedule—up to 1320 seconds (22 minutes). Römer explained this time difference by suggesting that light took longer to reach the earth from Jupiter when the earth was farther from Jupiter in its orbit around the sun. Huygens used Römer's data, together with a new value of 182,000,000 miles for the diameter of the earth's orbit, to calculate a value for the speed of light: 138,000 miles/second. Today's time lag value (996 seconds) and 2 AU value (185,800,000 miles) yield the more accurate figure of 186,300 miles/second.

Michelson's Terrestrial Method

Overlay B — This is a simplified diagram of the apparatus used by Michelson in the late 1920's. The octagonal mirror wheel allowed light to reflect from one surface to a mirror 22 miles away back to another surface on the wheel, and finally to an observer, as shown in the top diagram. When the mirror is rotated, the change in its position while the light travels the 44-mile round trip causes the beam at the detector to shift, as shown in the second diagram. If the wheel rotates at 530 revolutions per second, the light beam is found to appear in exactly the same position as when the wheel was stationary. This means that while the beam was traveling the 22 miles to the distant mirror and back, the mirror wheel turned ⅛ of a revolution, as shown in the bottom diagram. Since one revolution takes 1/530 seconds, ⅛ of a revolution takes ⅛ x 1/530 second or 2.36 x 10^{4} seconds. Dividing 44 miles by this time yields 186,300 miles/second.

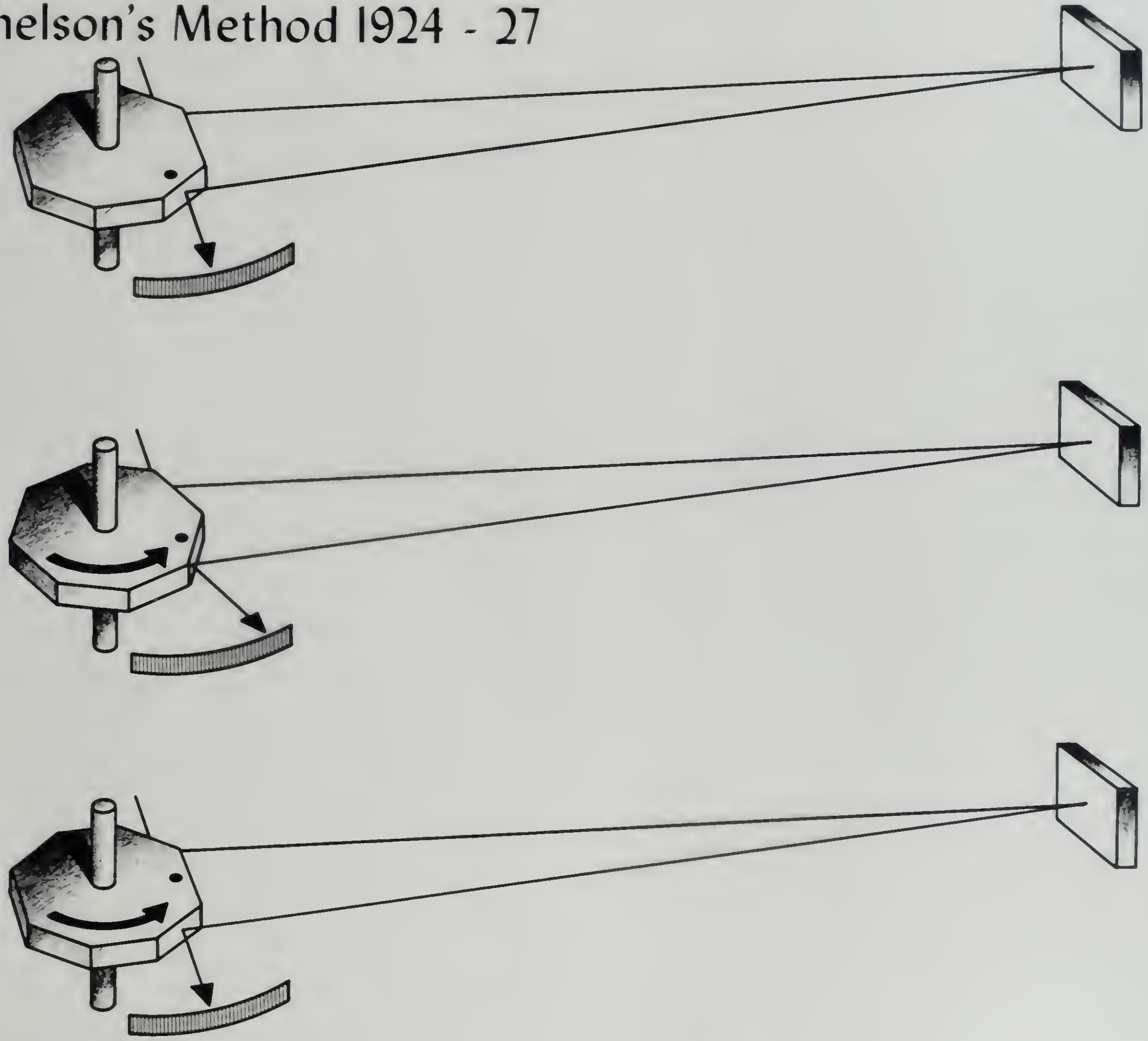
A

Römer's Method 1676



B

Michelson's Method 1924 - 27



T31

$\vec{E}$ Field Inside Conducting Sphere

$\vec{E}$ Field Inside Conducting Sphere

This transparency is useful in discussing the electric field strength inside a charged hollow sphere. Applications of shielding techniques can be brought up.

Overlay A A hollow metal sphere is shown with positive charge spread evenly over its entire surface. The small black dot represents an arbitrary point within the sphere at which investigations concerning electric fields can be made.

Overlay B As the double "cone" indicates, a small patch on the surface of the sphere on one side of the point has a corresponding patch on the other side. The charges, Q_1 and Q_2, on these patches are proportional to their areas, A_1 and A_2:

$$\frac{Q_1}{Q_2} = \frac{A_1}{A_2}$$

Overlay C Since these patches are marked out by the same "cone", their areas are proportional to the squares of the distances from the chosen point.

$$\frac{A_1}{A_2} = \frac{d^2_1}{d^2_2} \text{ and therefore } \frac{Q_1}{Q_2} = \frac{d^2_1}{d^2_2}$$

The electric field due to each patch is proportional to the charge on the patch and also is inversely proportional to the square of the distance from the chosen point, so:

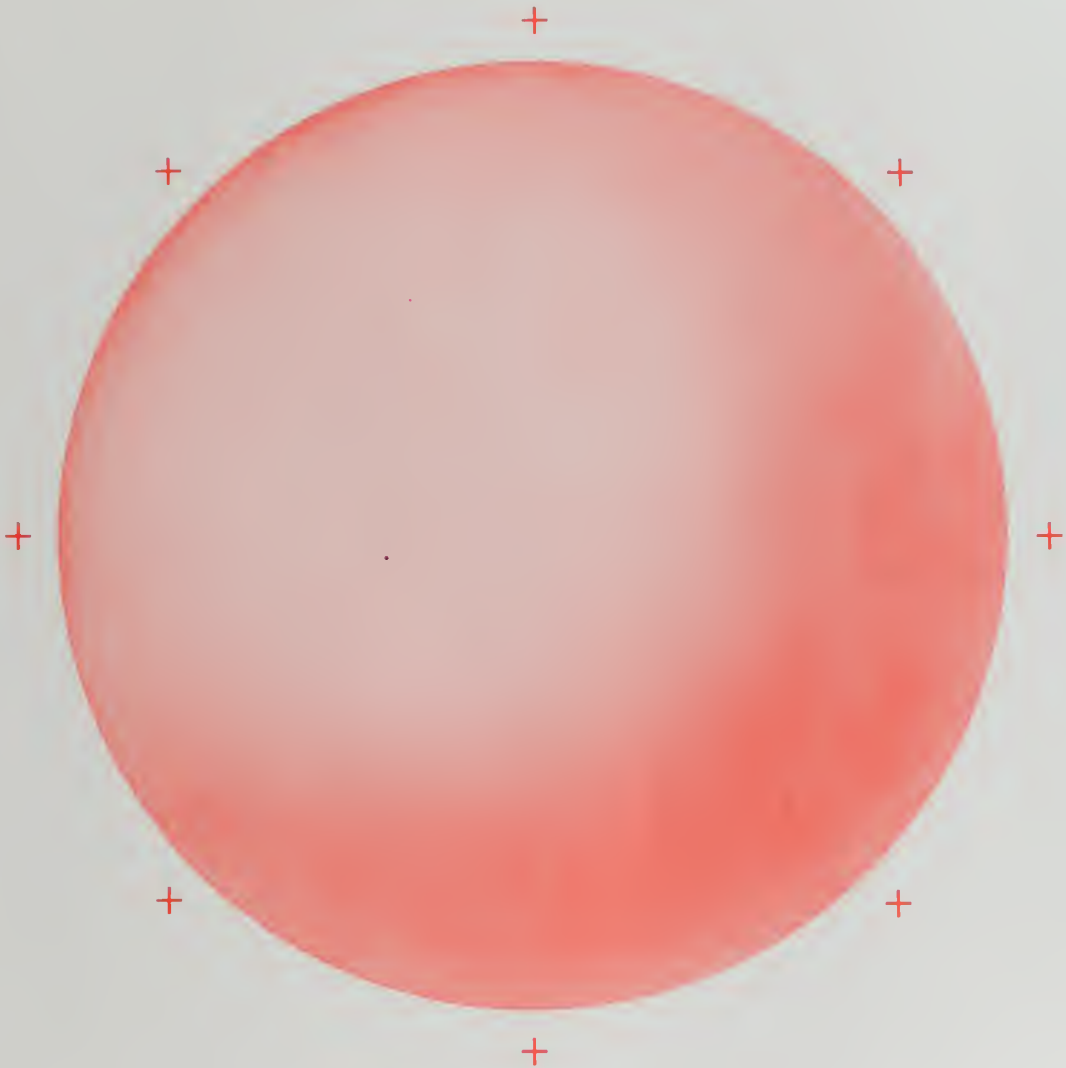
$$\begin{aligned} \frac{E_1}{E_2} &= \frac{Q_1}{Q_2} \times \frac{d^2_2}{d^2_1} \\ &= \frac{d^2_1}{d^2_2} \times \frac{d^2_2}{d^2_1} \\ &= 1 \end{aligned}$$

Hence the distance and area factors balance and the $\vec{E}$ fields due to the two patches at the point are exactly equal (and opposite).

Overlay D Using the same argument for other "cones" leads to similar results. Indeed, it is true for all pairs of charge patches, so the net electric field at the arbitrary point is zero.

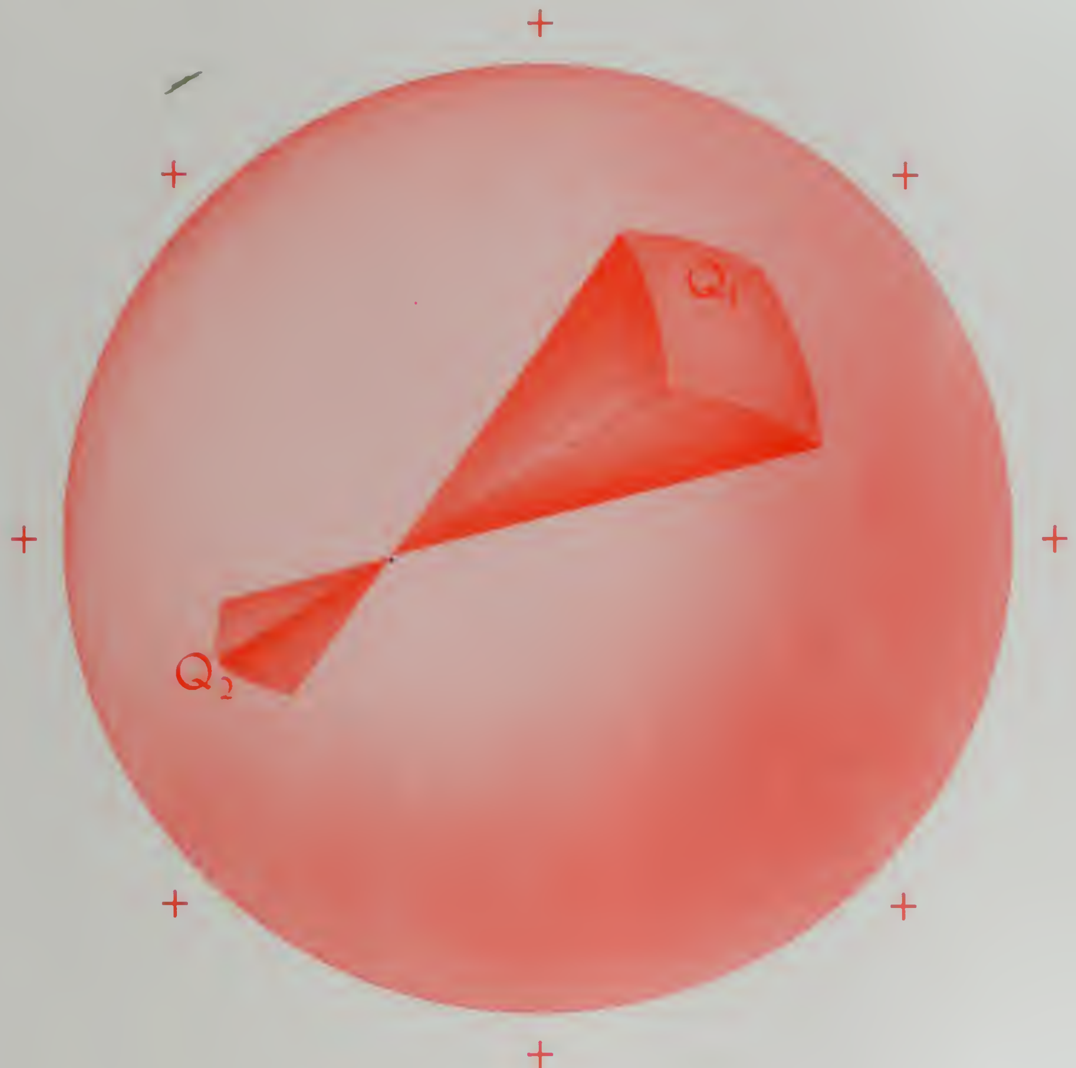
T-31

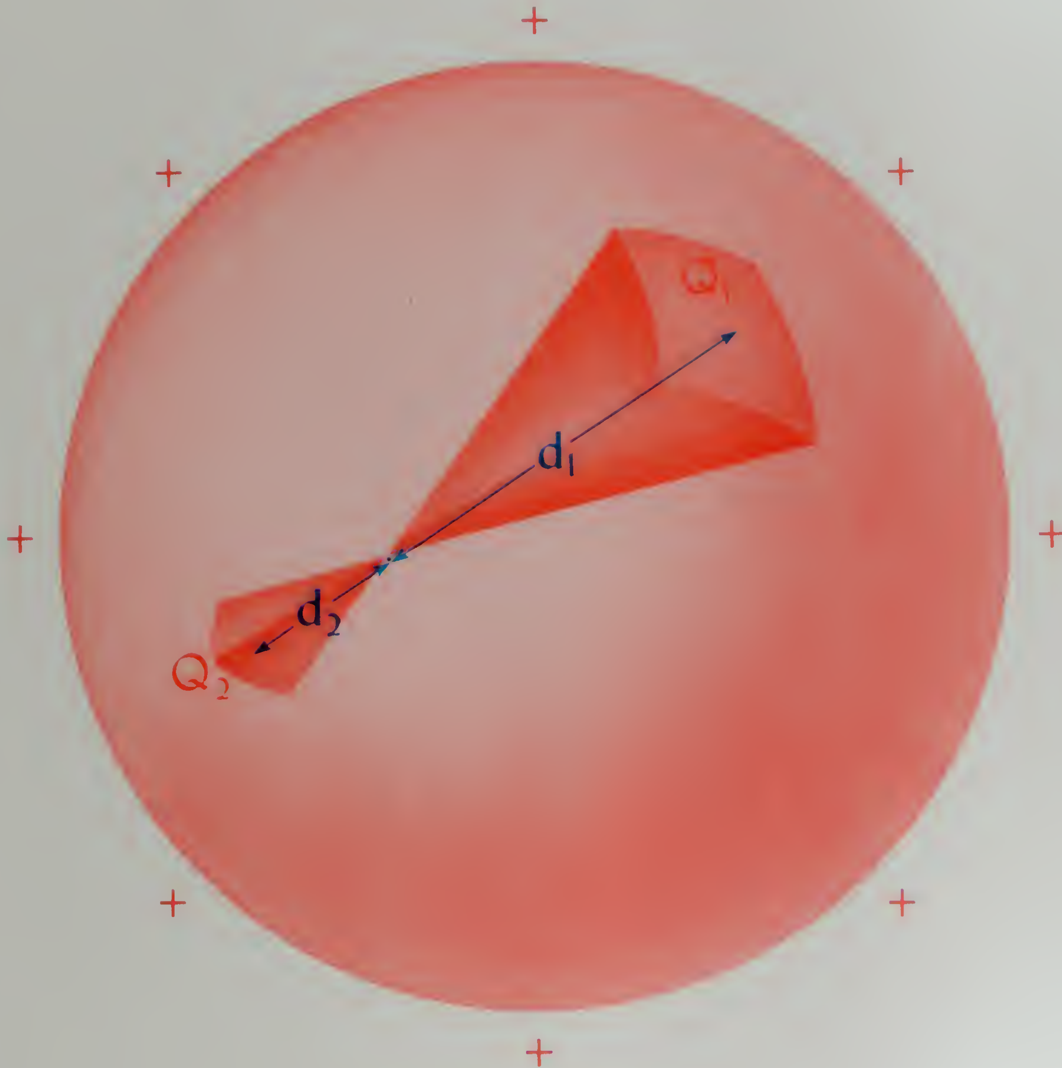
A

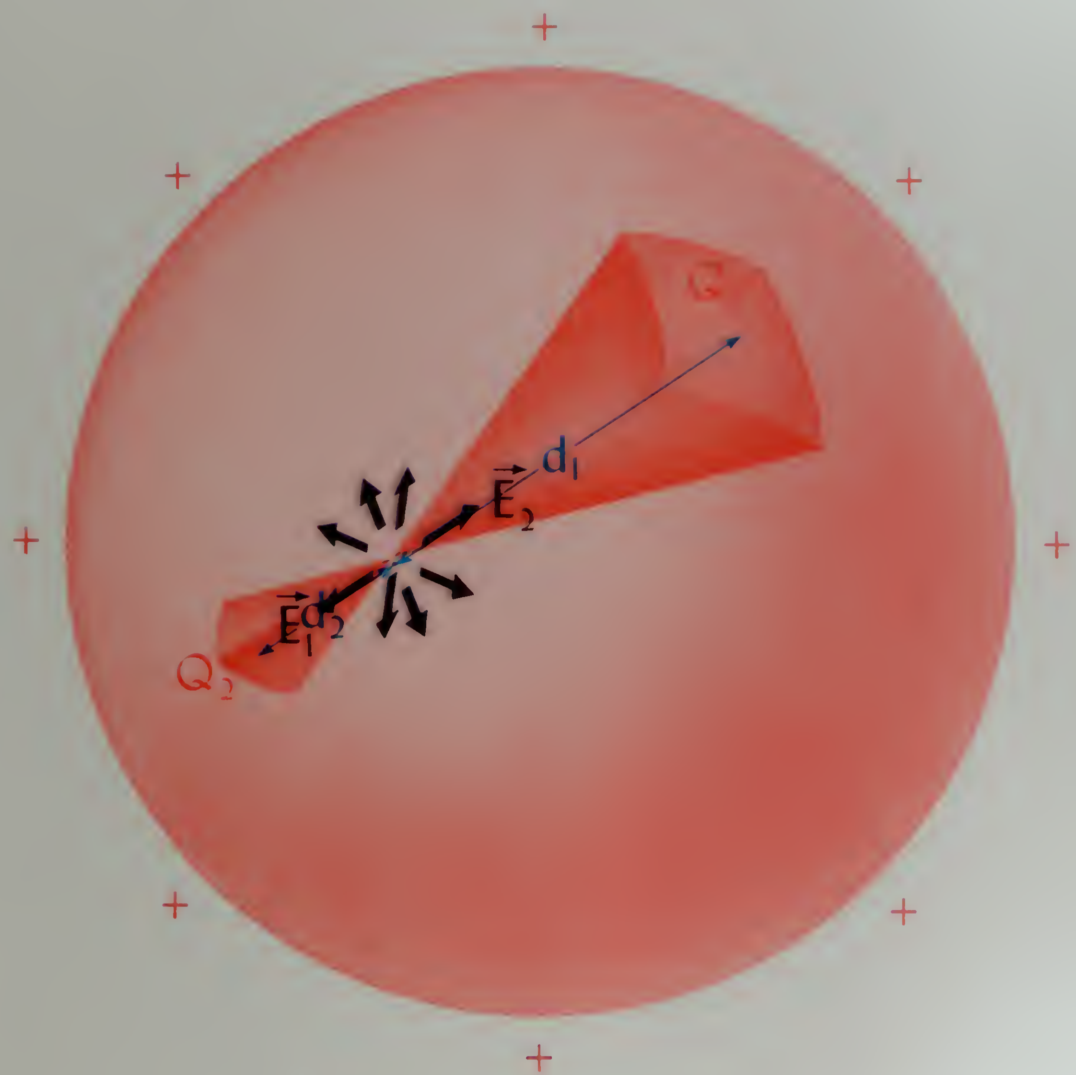


T-31

A
B




Q1
d1
d2
Q2



A
B
C
D

Magnetic Fields and Moving Charges

This transparency will be useful in discussing a number of phenomena which can occur in magnetic fields: forces on moving charged particles; forces on charged particles in both magnetic and electric fields; forces on current carriers; forces on moving conductors. Portions of this transparency are applicable in Unit 5 also.

Overlay A — This shows the poles of a strong magnet producing a magnetic field with a suggestion of fringing shown at the edges.

Overlay B — A negatively charged particle moves in the uniform portion of the magnetic field $\vec{B}$ with a velocity $\vec{V}$. Cover the upper two representations with an index card and discuss the consequences of the force acting on the charged particle at right angles to both $\vec{V}$ and $\vec{B}$. Ask students to predict the behavior of the particle and then reveal the next two illustrations. Students should quickly realize that the path of the particle must be a segment of a circle, since the force continually acts at right angles to the velocity.

Overlay C — An arrow indicates the curved path that a negatively charged particle might follow when moving in a uniform magnetic field at right angles to $\vec{B}$. Of course, the path could be a complete circle if the proper conditions are met. Remove overlays A, B, and C.

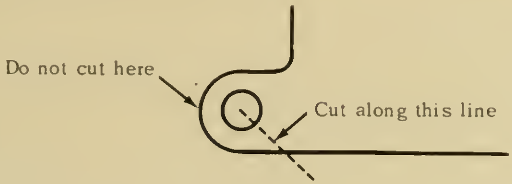
Overlay D — A set of charged plates produces a strong uniform electric field (without a suggestion of fringing shown at the edges). Ask students to predict the path that a negative particle will take when fired into the field with a constant velocity. Ask about a positive particle, also. The paths of course will be parabolic downward (negative particle) and upward (positive). Introduce overlay E.

Overlay E — This shows the parabolic path taken by a negatively charged particle entering a uniform electric field at right angles to .$\vec{E}$ Return overlays A and C and discuss the two forces due to the magnetic and electric fields which now act on the particle. Remove overlays C and E and introduce overlay F.

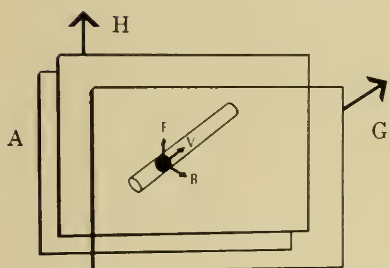
Overlay F — The path that a negatively charged particle will take in the combined magnetic and electric fields is a straight line if the forces caused by the respective fields are equal. Remove overlay F.

Magnetic Fields and Moving Charges (continued)

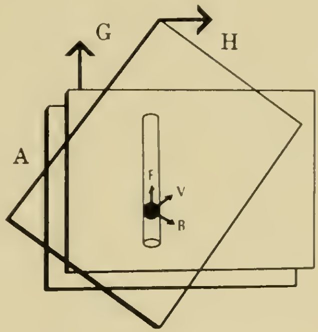
Overlay G This is a detachable overlay which illustrates the mutually perpendicular vectors $\vec{F}$, $\vec{V}$, and $\vec{B}$ which operate on a moving negatively-charged particle in a magnetic field (according to the left hand rule). Use it with overlay H to illustrate the generator and motor principles. Overlays G and H can be made easily detachable by carefully cutting the binding ring as shown in this sketch.



Overlay H This detachable overlay representing a segment of metallic wire. With overlay A in place on the stage, align overlays G and H so that the charged particle is positioned inside the wire. Now assume that electrons are flowing to the right through the wire. Since the magnetic field is perpendicular to the velocity of the electrons, there will be a force exerted on the electrons in an upward direction according to the (left) hand rule. Such a force on the flowing electrons pushes the entire wire upward. You can illustrate this phenomenon by carefully sliding the overlays in the proper directions as indicated in the diagram. (The arrow for G shows its motion relative to the moving H.)



The Motor Principle

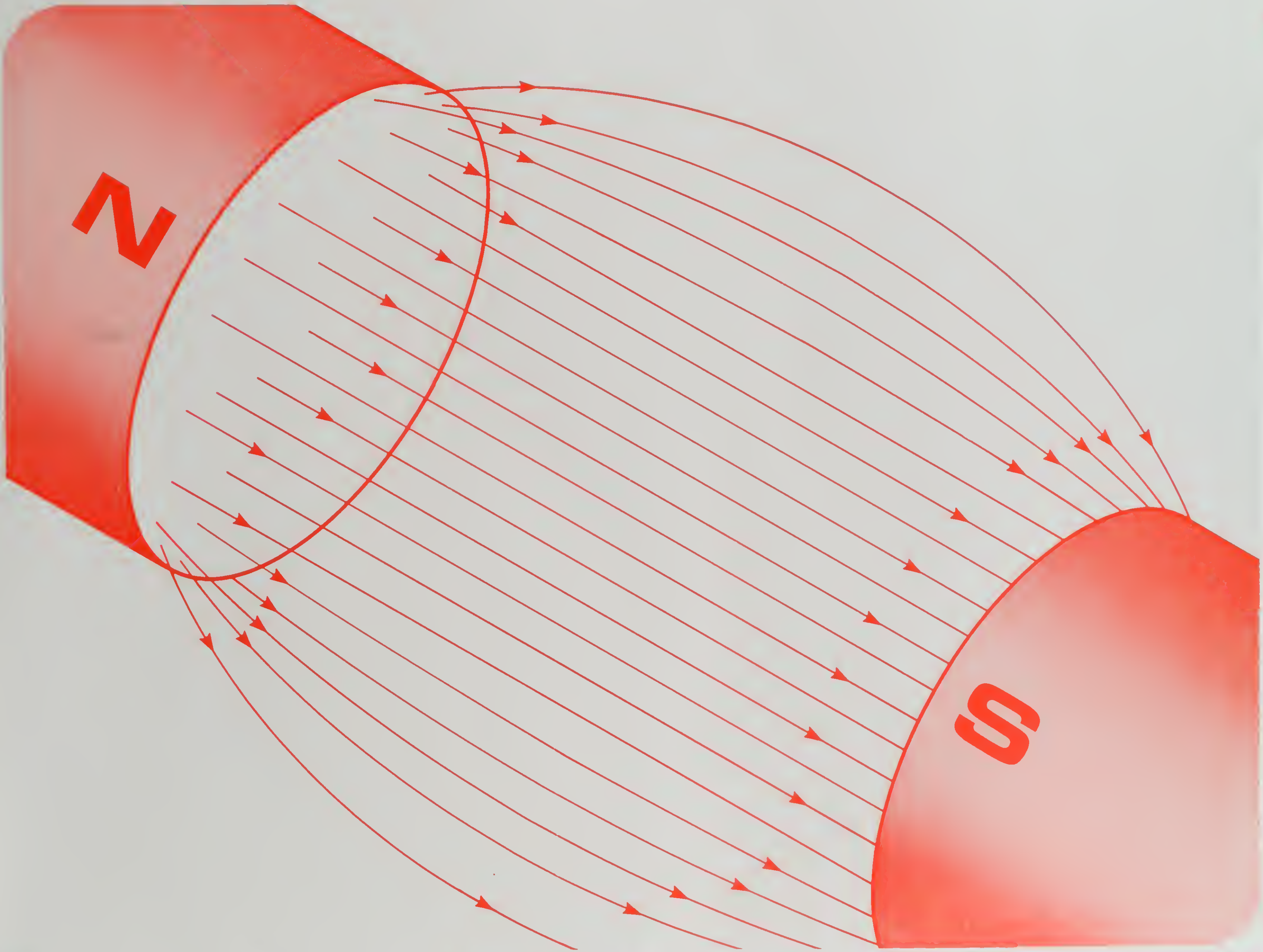


The Generator Principle

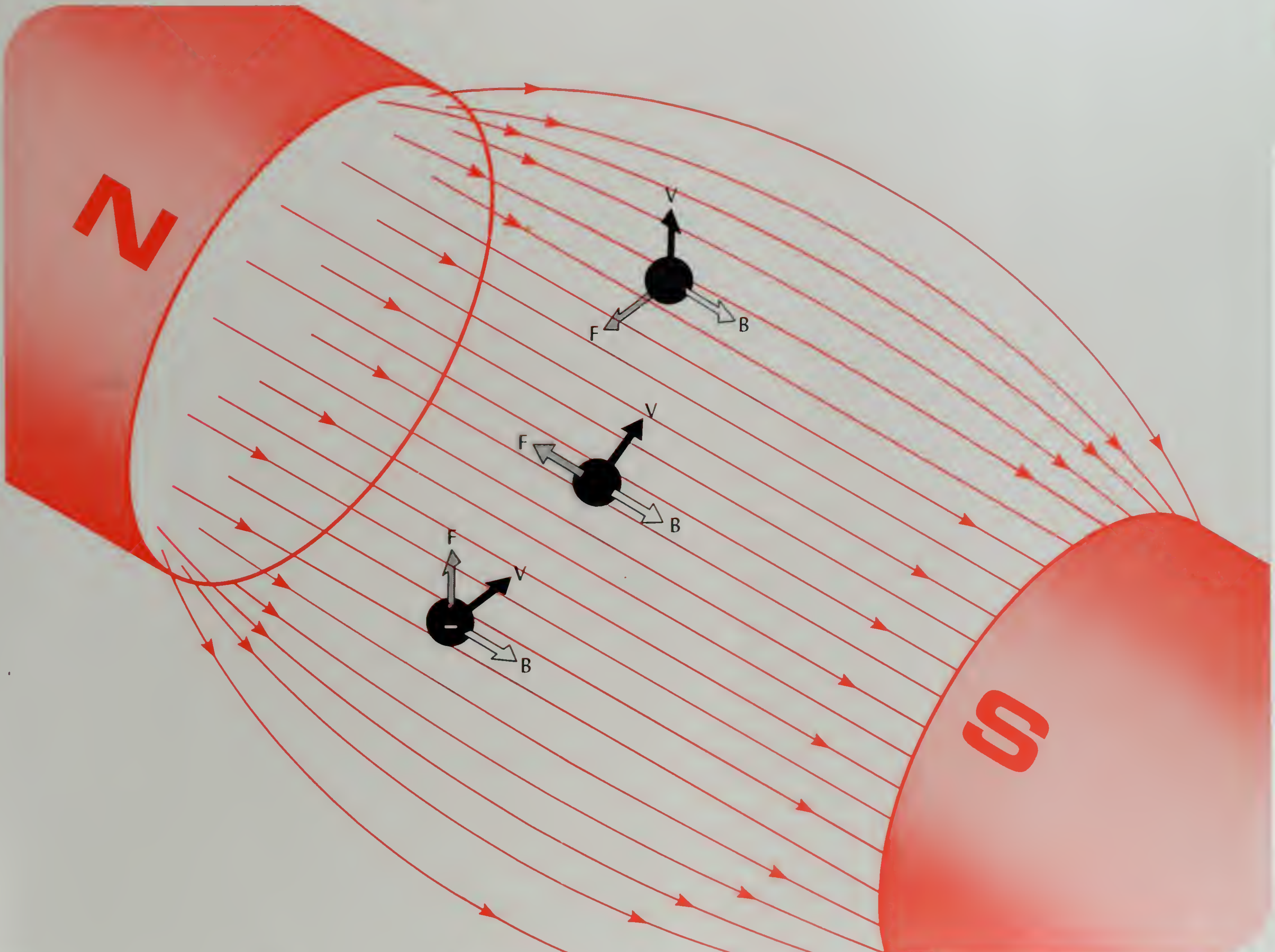
When a wire is moved at right angles to $\vec{B}$ through a magnetic field there will be produced a deflecting force on the free electrons in the wire thus producing an electron displacement. If the wire is part of a closed loop, a current is produced as mechanical energy is converted into electrical energy. (If the loop is not closed, the displacement will produce an excess of electrons at one end of the moving wire and a deficiency of electrons at the other.) You can illustrate the operation of this principle by orienting overlays G and H as shown in the diagram and move them in the directions indicated. (The arrow for G shows its motion relative to the moving H.)

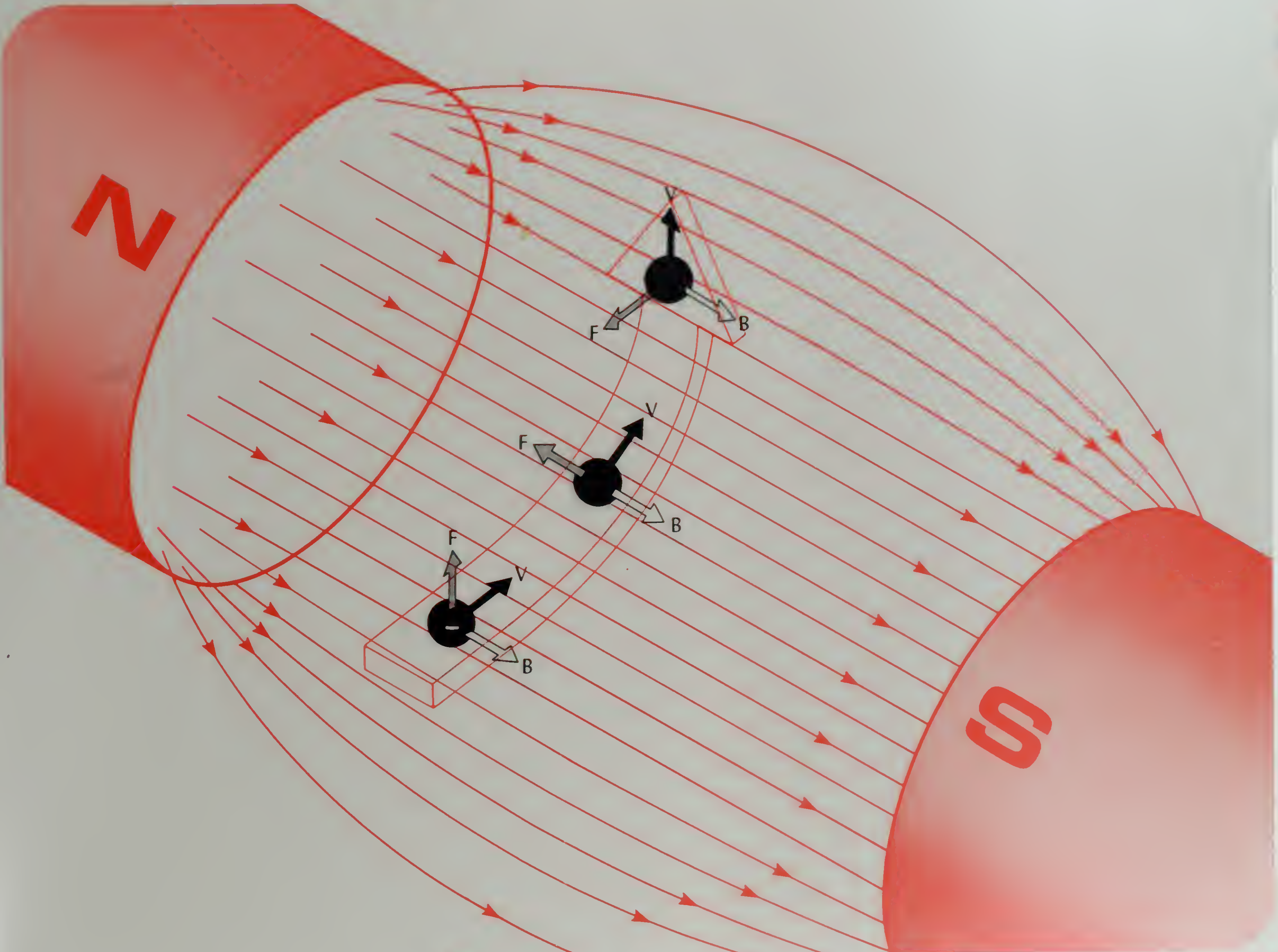
T-32

A

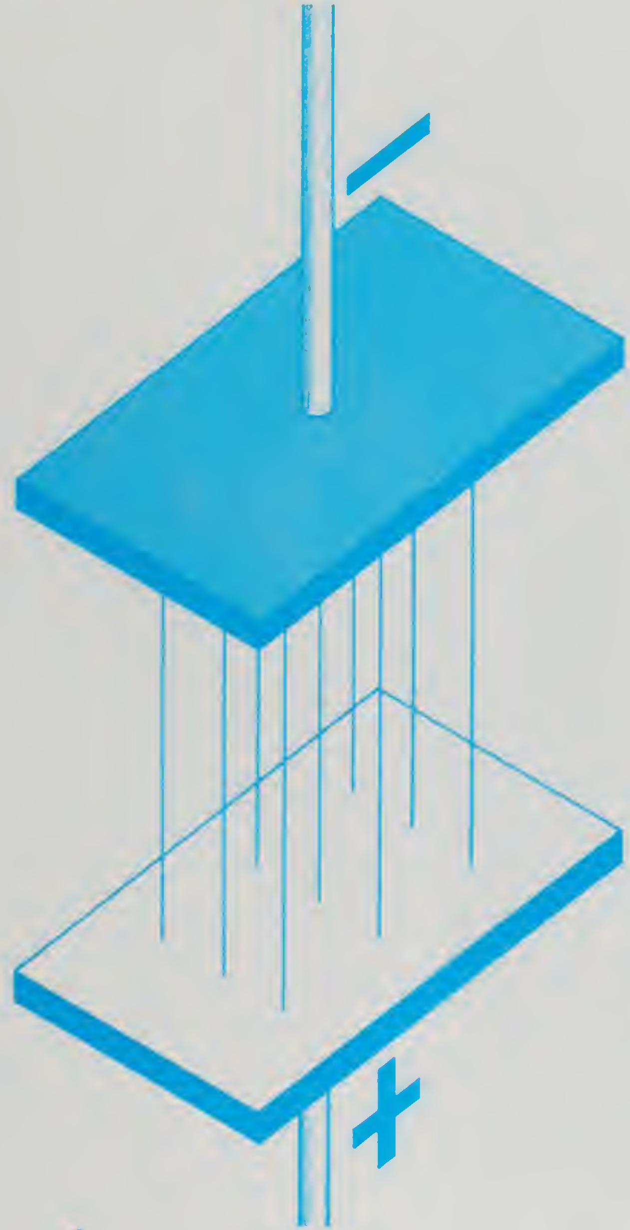


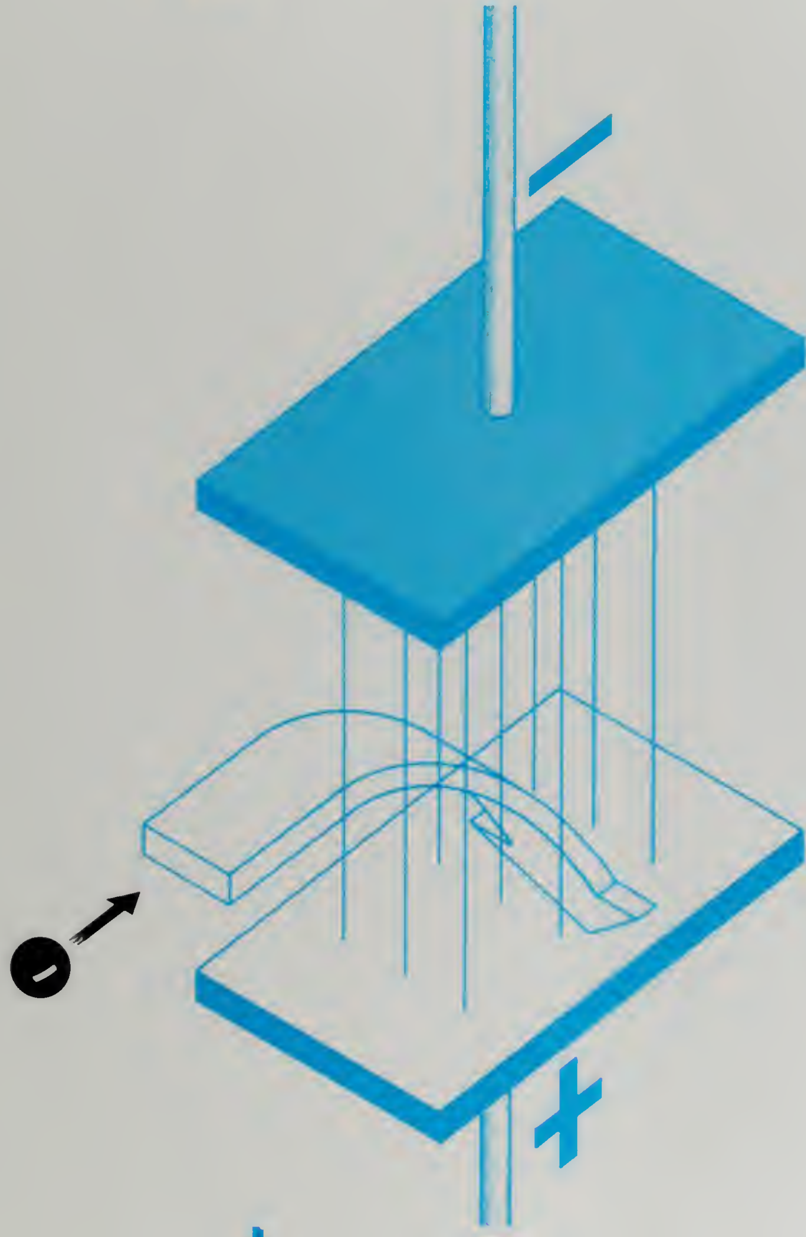
A
B




N
S
V
F
B
V
F
B
F
V
B
-

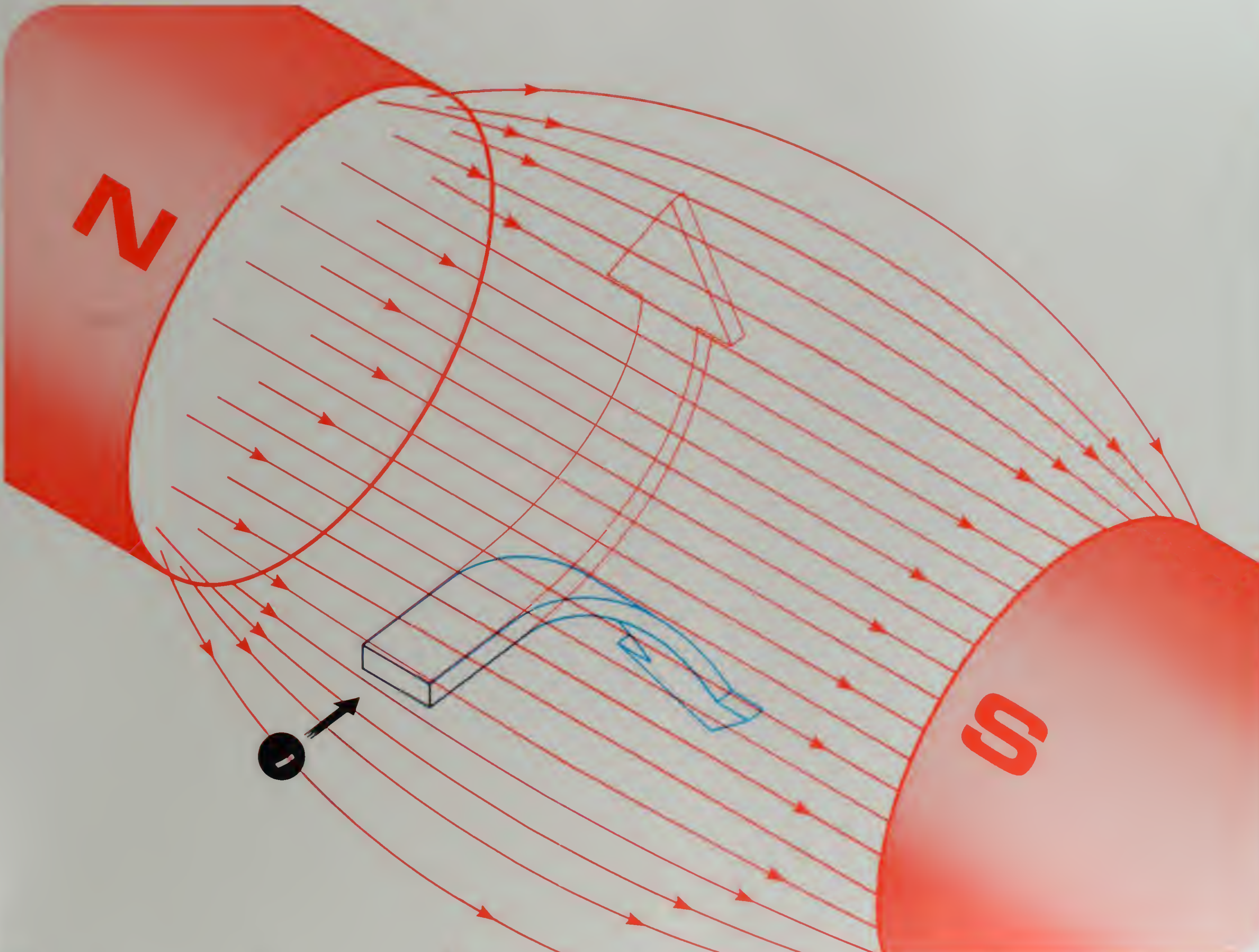
D

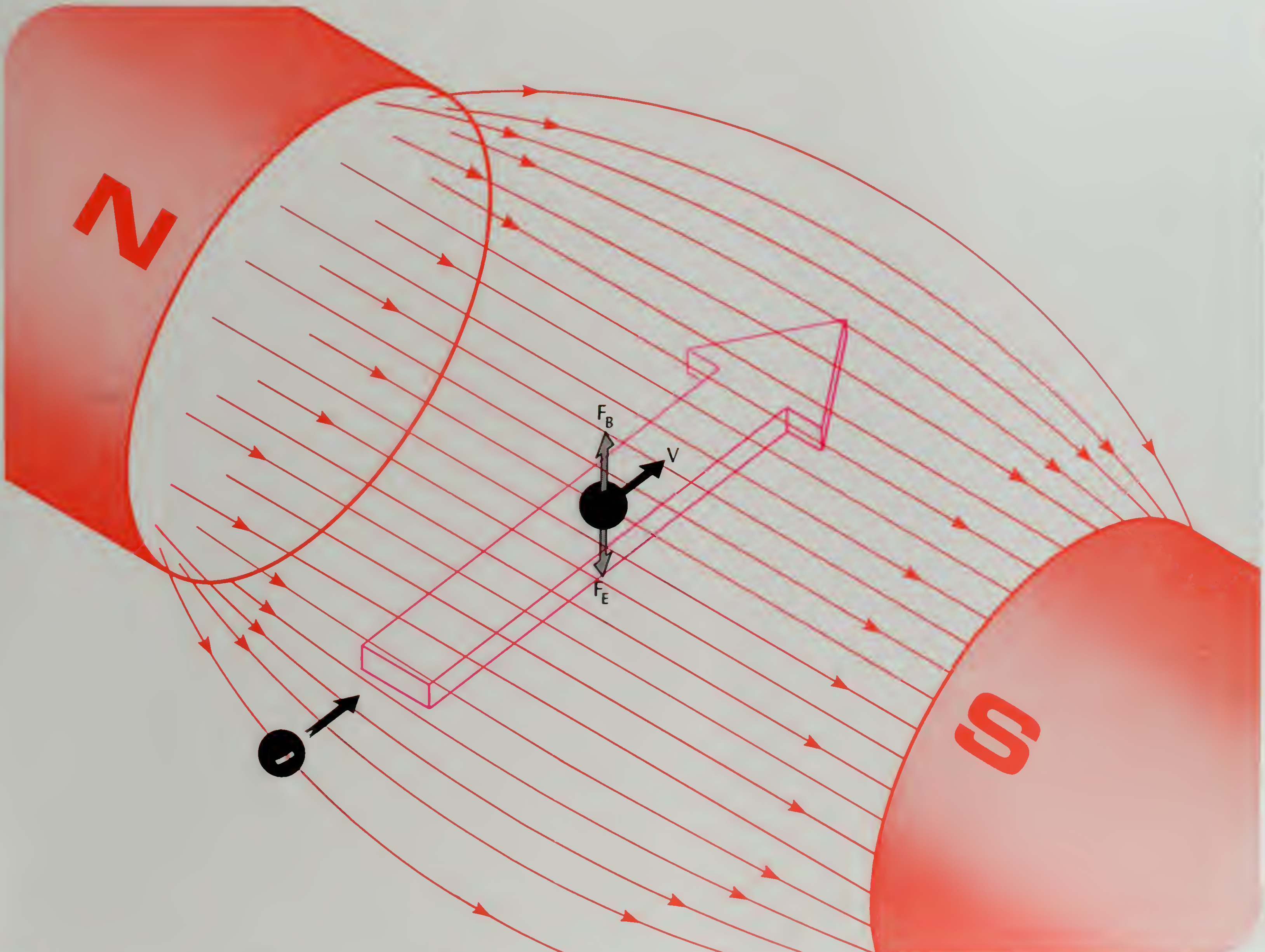




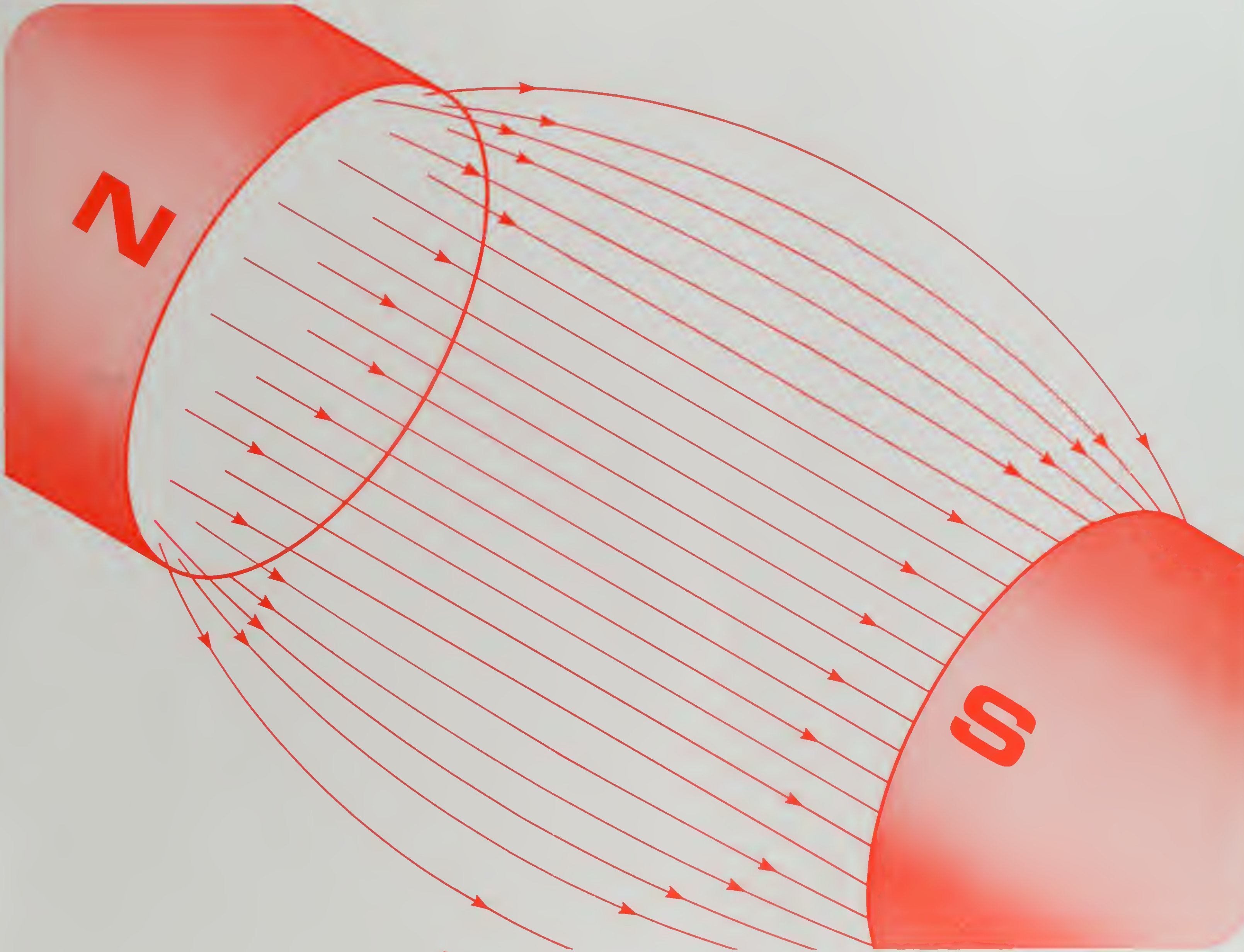
D
E

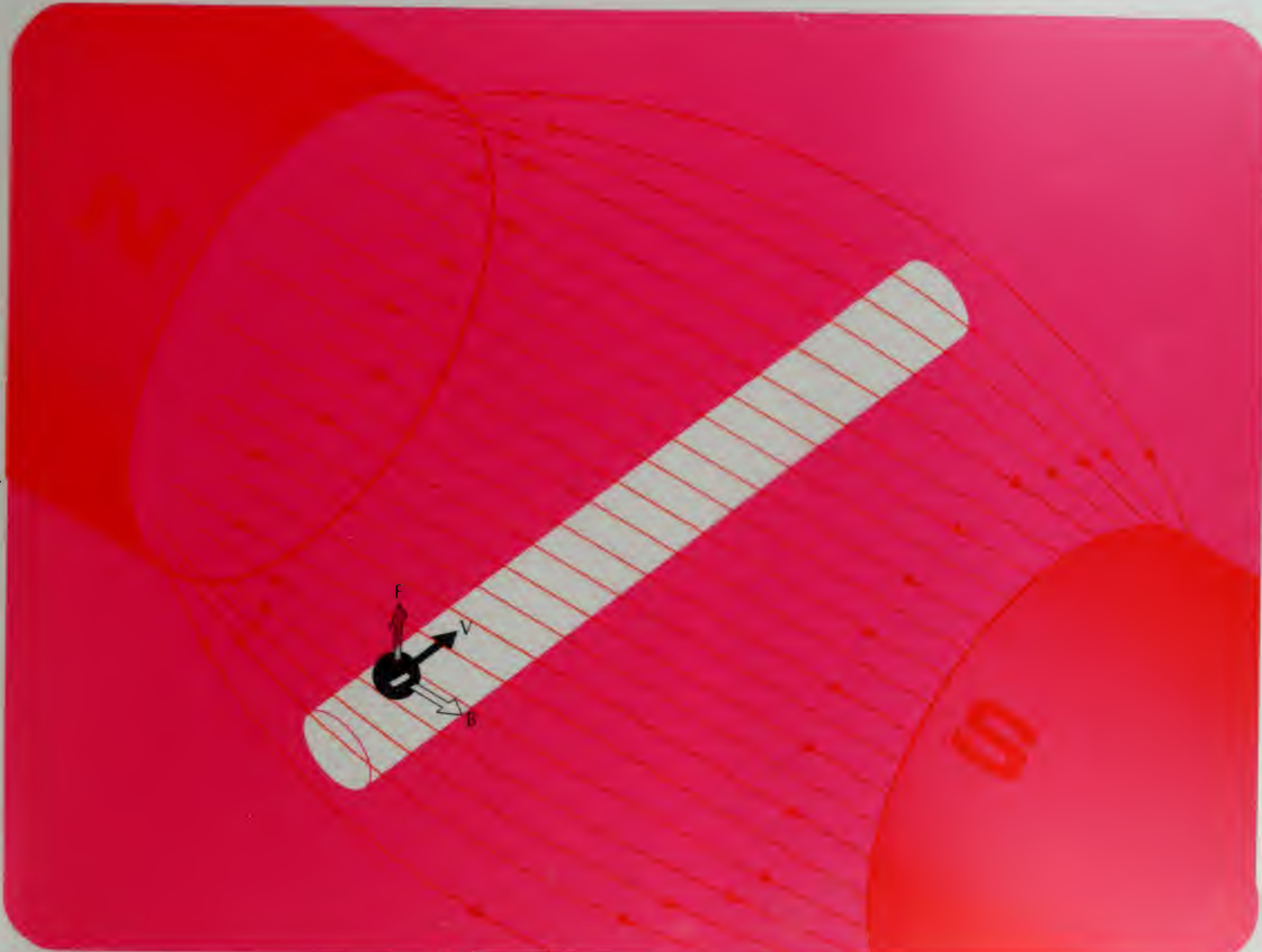
A
C
E





A F


N
S


F
V
B
N
S

Forces Between Current Carriers

T33

Forces Between Current Carriers

This transparency provides an account of the forces produced between two parallel current carriers, based on the principles governing moving charged particles in magnetic fields (see T32). It should prove very useful when used in connection with the Current Balance Experiment.

Overlay A The enlarged segments of two parallel conductors.

Overlay B A battery and connection complete a circuit. The arrows indicate the direction of electron flow. In this circuit, the electron flow in the parallel conductors is in opposite directions.

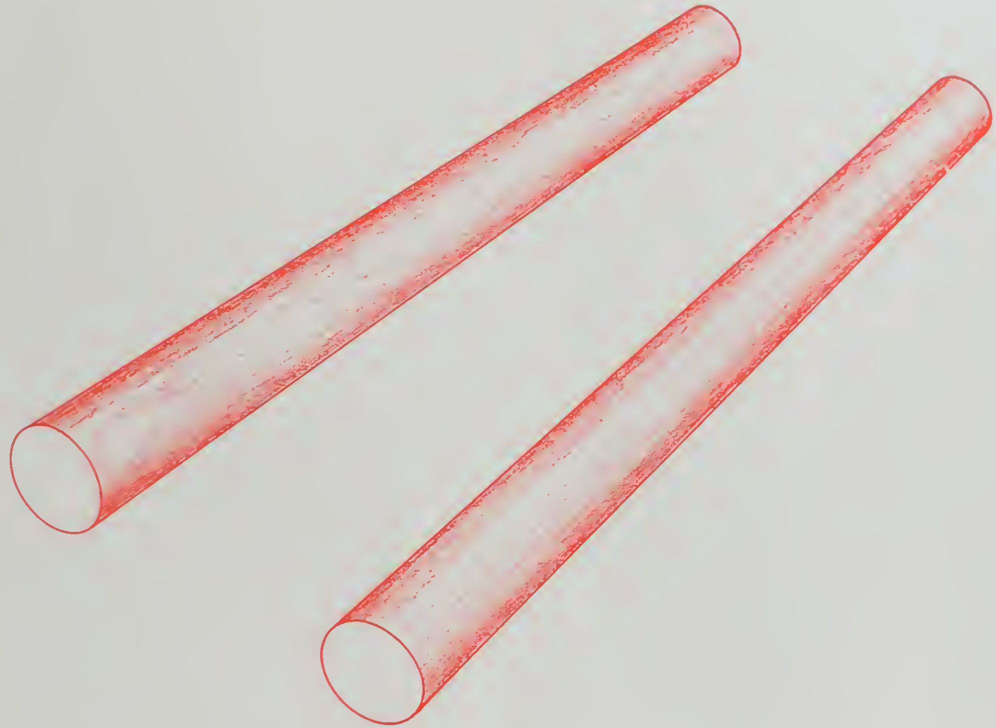
Overlay C Magnetic field lines surround the left wire as determined by the (left) hand rule. An electron is shown moving to the right in the field created by the left wire. The force on the electron, and consequently on the entire wire, will be outward, that is, away from the other wire. Remove this overlay and introduce overlay D.

Overlay D The magnetic field produced by the right wire will cause an outward force on the moving electron in the left wire. Return overlay C and note that wires with anti-parallel currents will repel each other. Remove overlays B, C, and D.

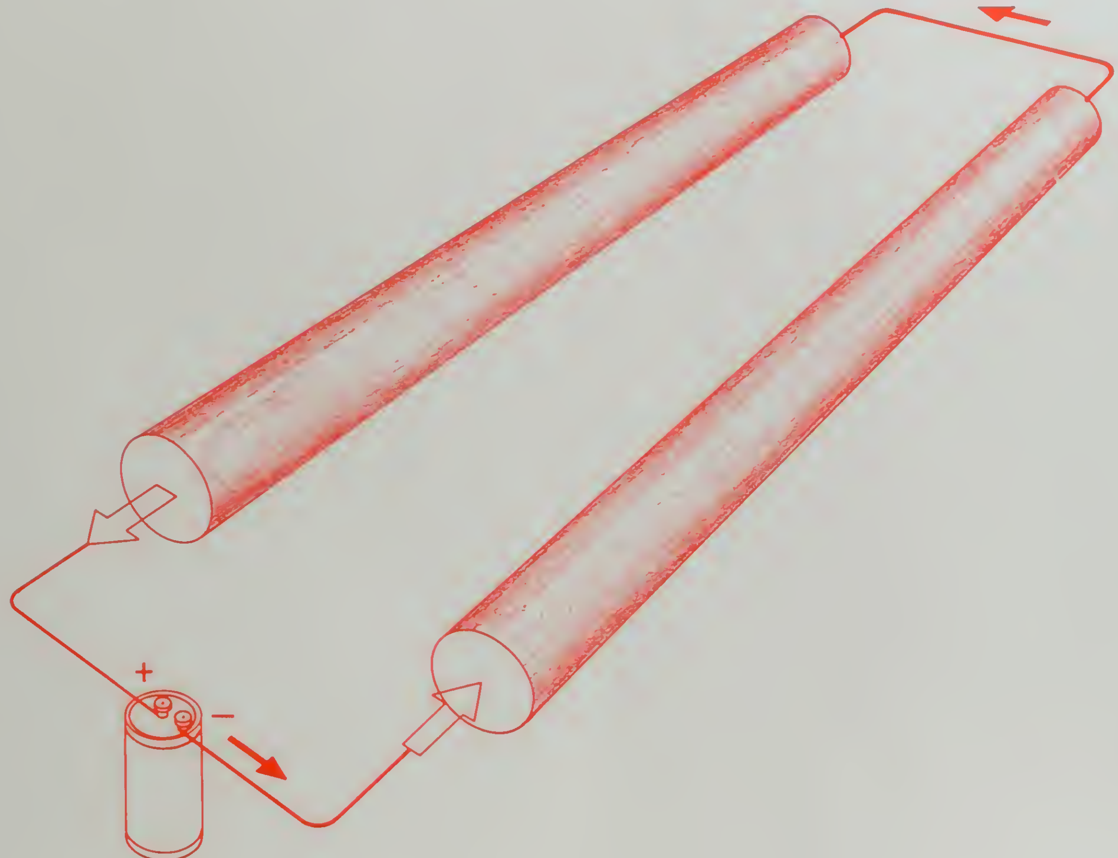
Overlay E In this different completed circuit the electron flow is now in the *same* direction in the two wires.

Overlay F Magnetic field lines surround the left wire as determined by the (left) hand rule. An electron is shown moving to the left in the field created by the left wire. The force on the electron, and consequently on the entire wire, is seen to be inward, that is, toward the other wire. Remove this overlay and introduce overlay G.

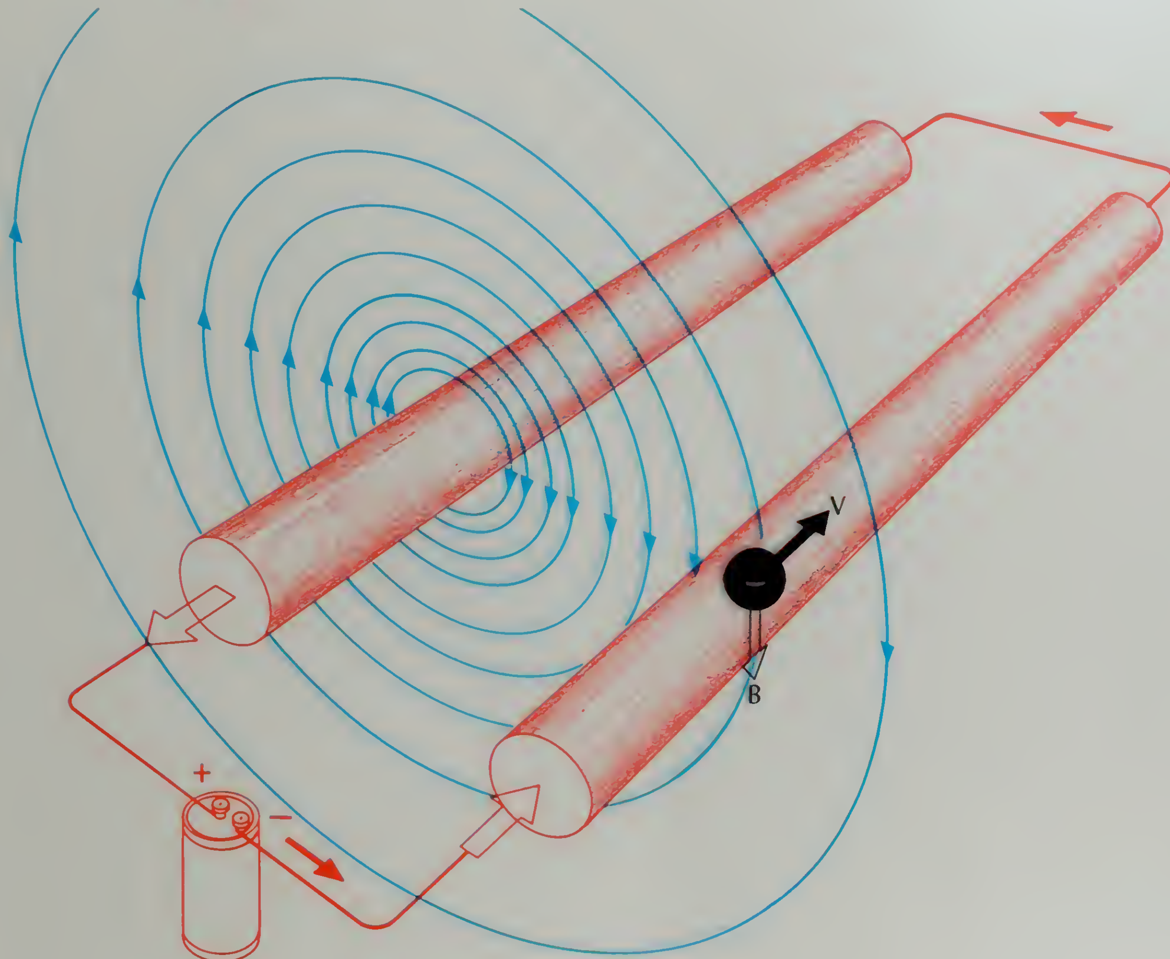
Overlay G The magnetic field produced by the right wire will have an effect on the moving electron in the left wire. Return overlay F and note that wires with parallel currents attract each other.



A
B

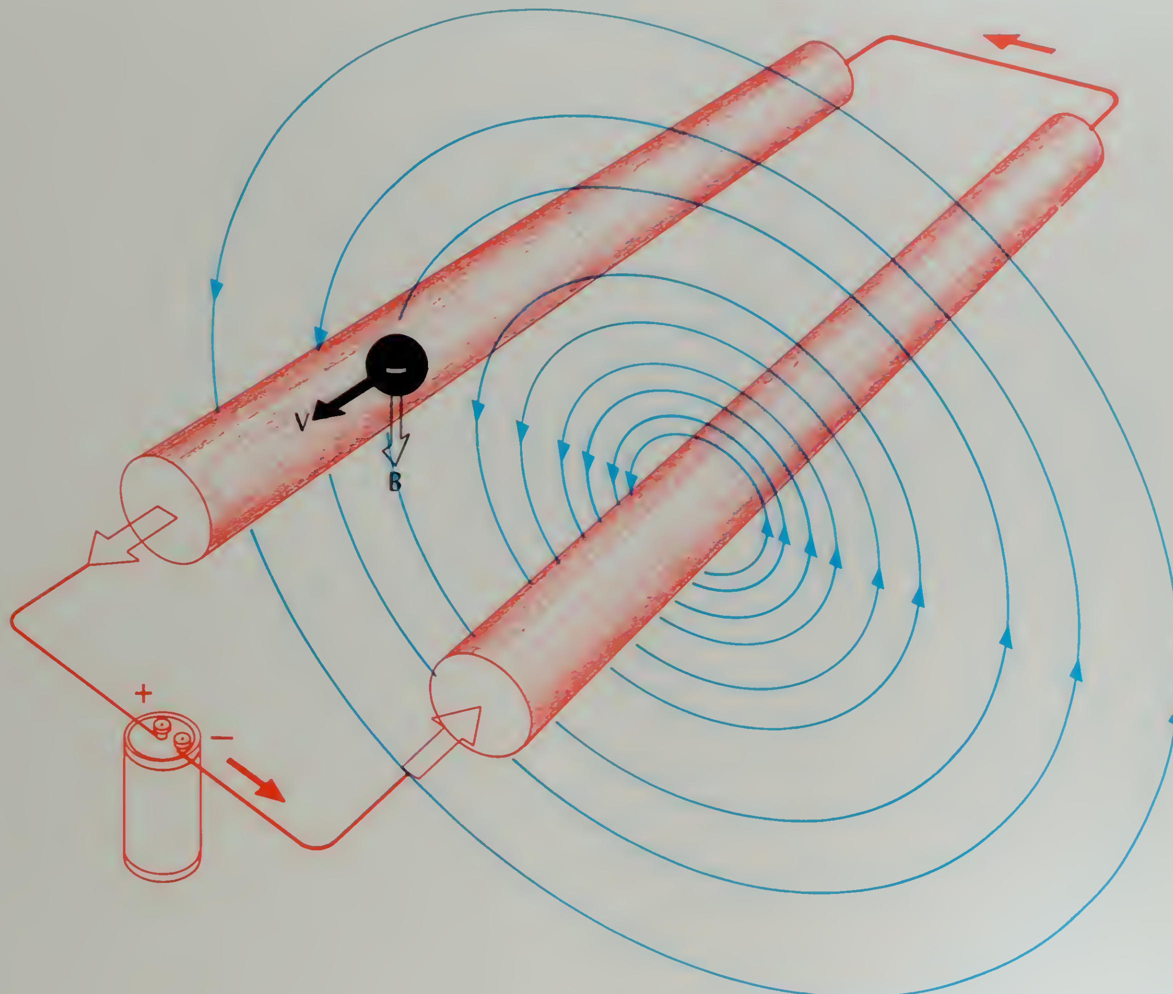


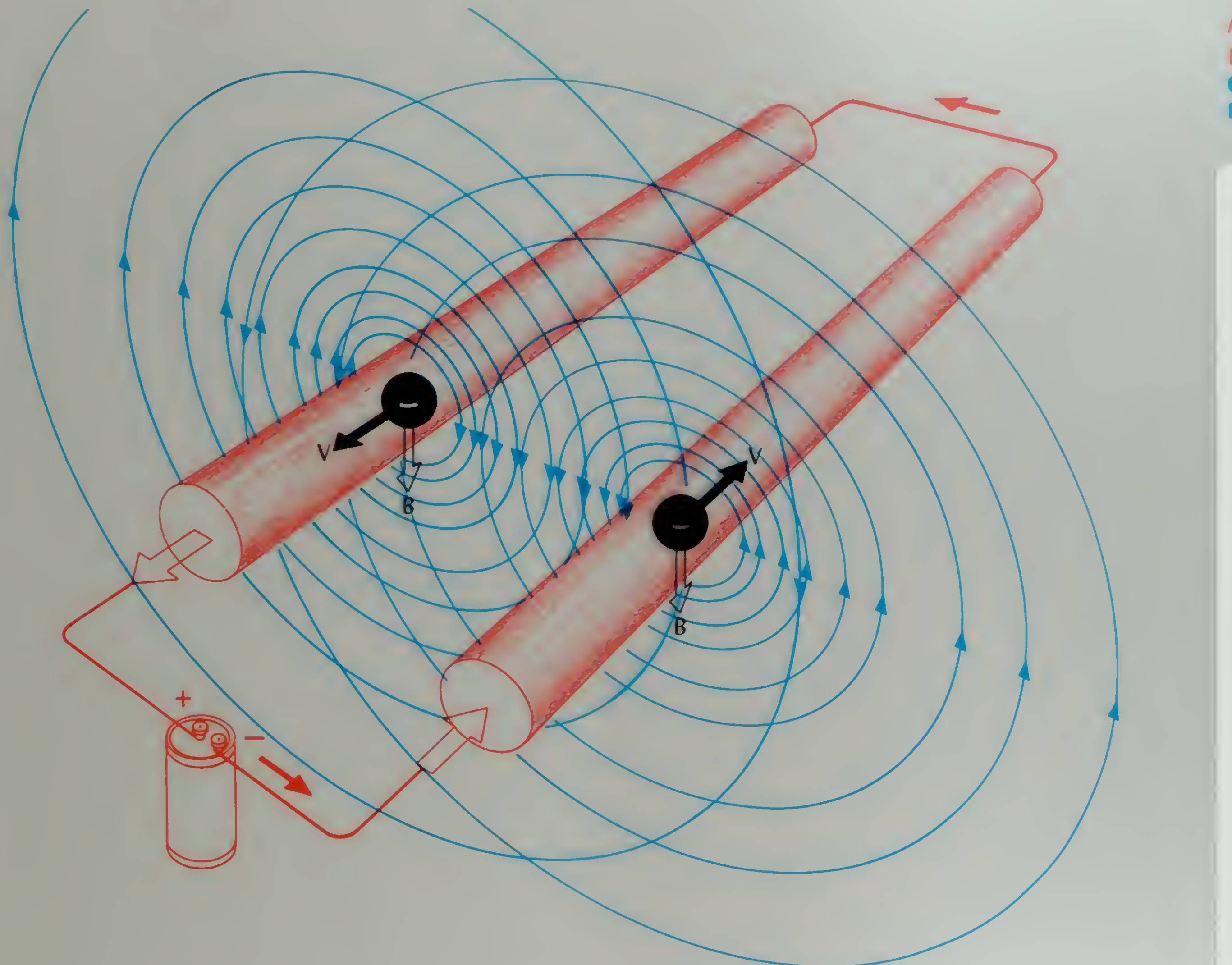
A
B
C



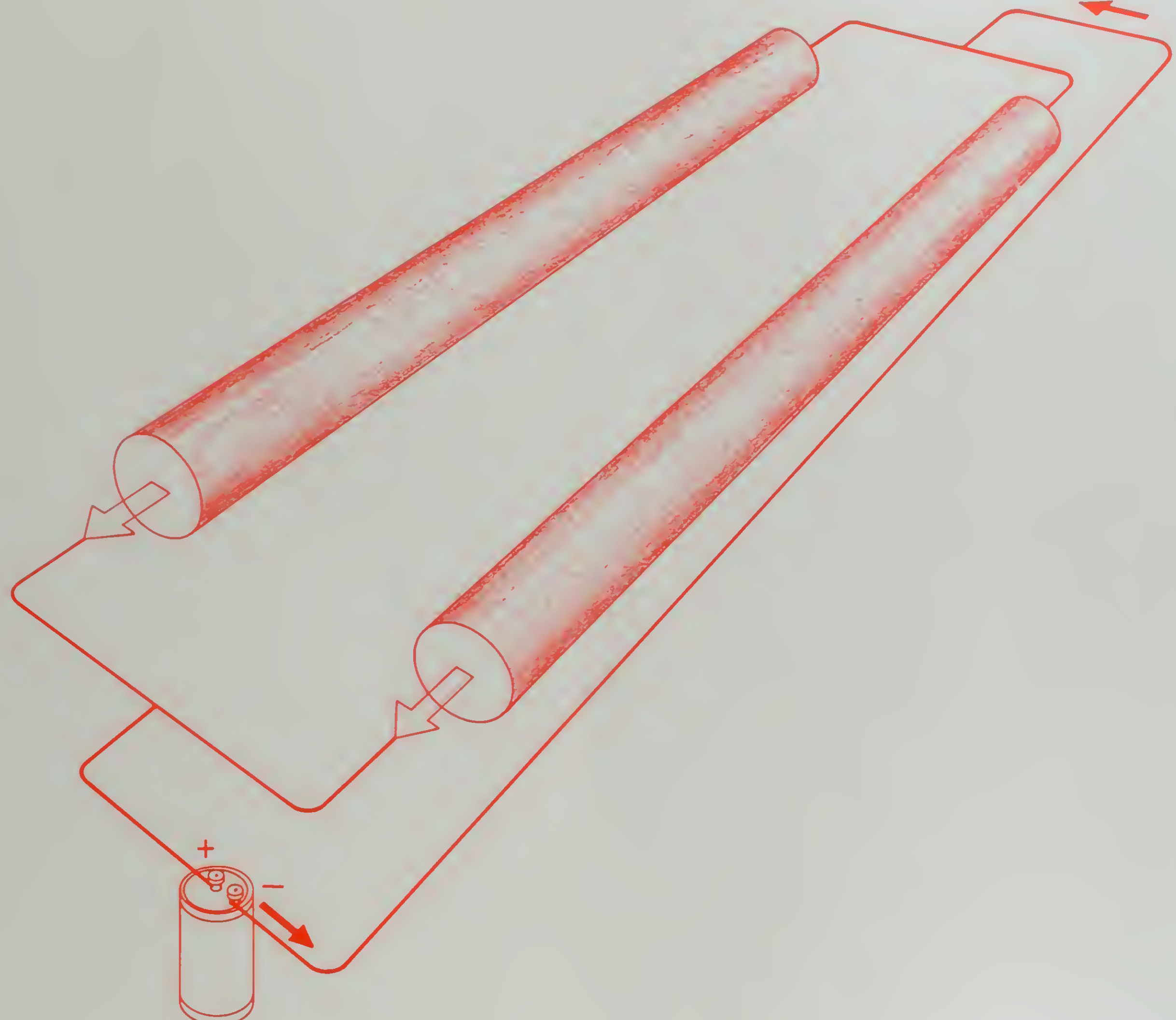
A
B

D



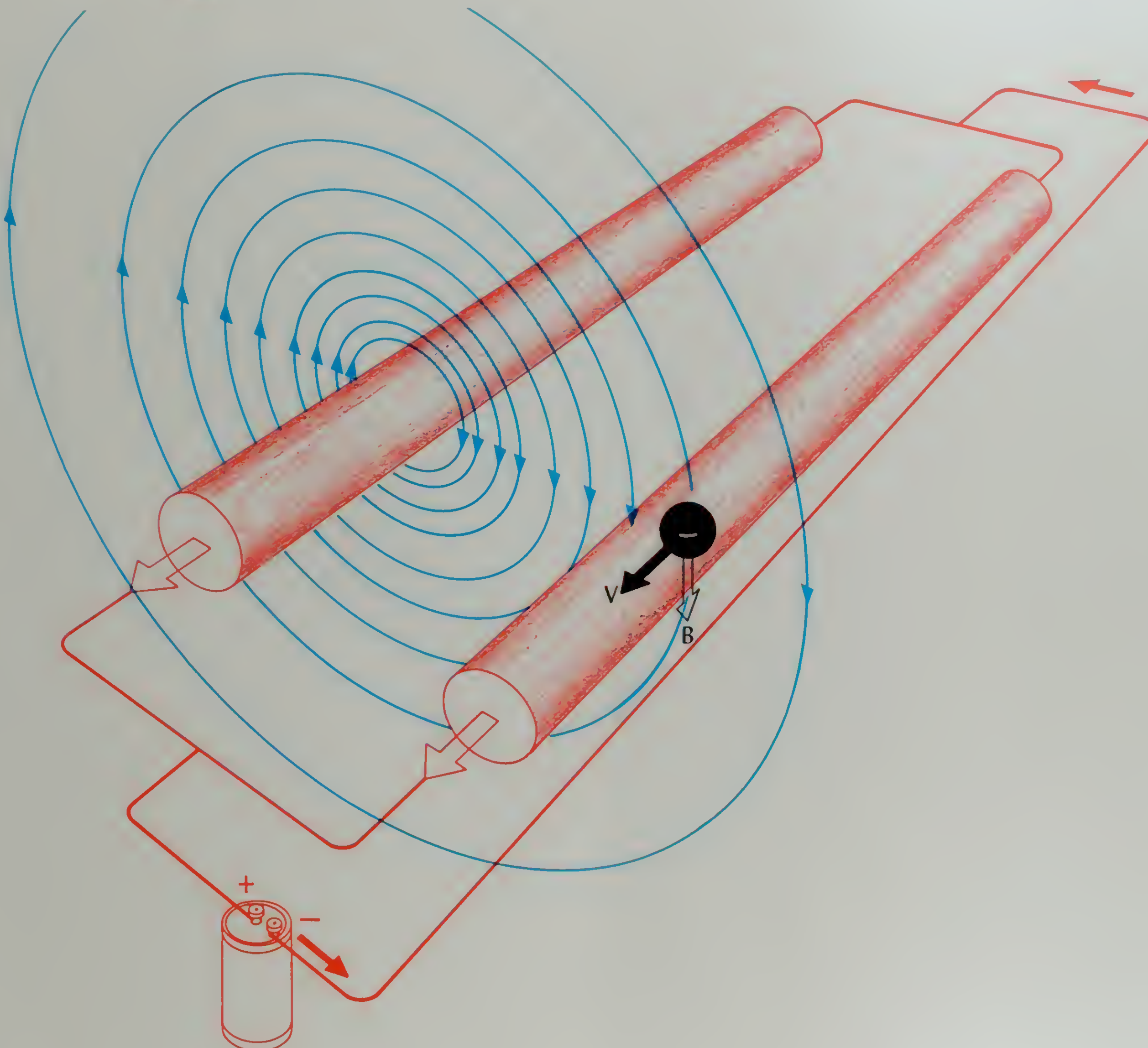


A
B
C
D
V
B
V
B
+
−



A

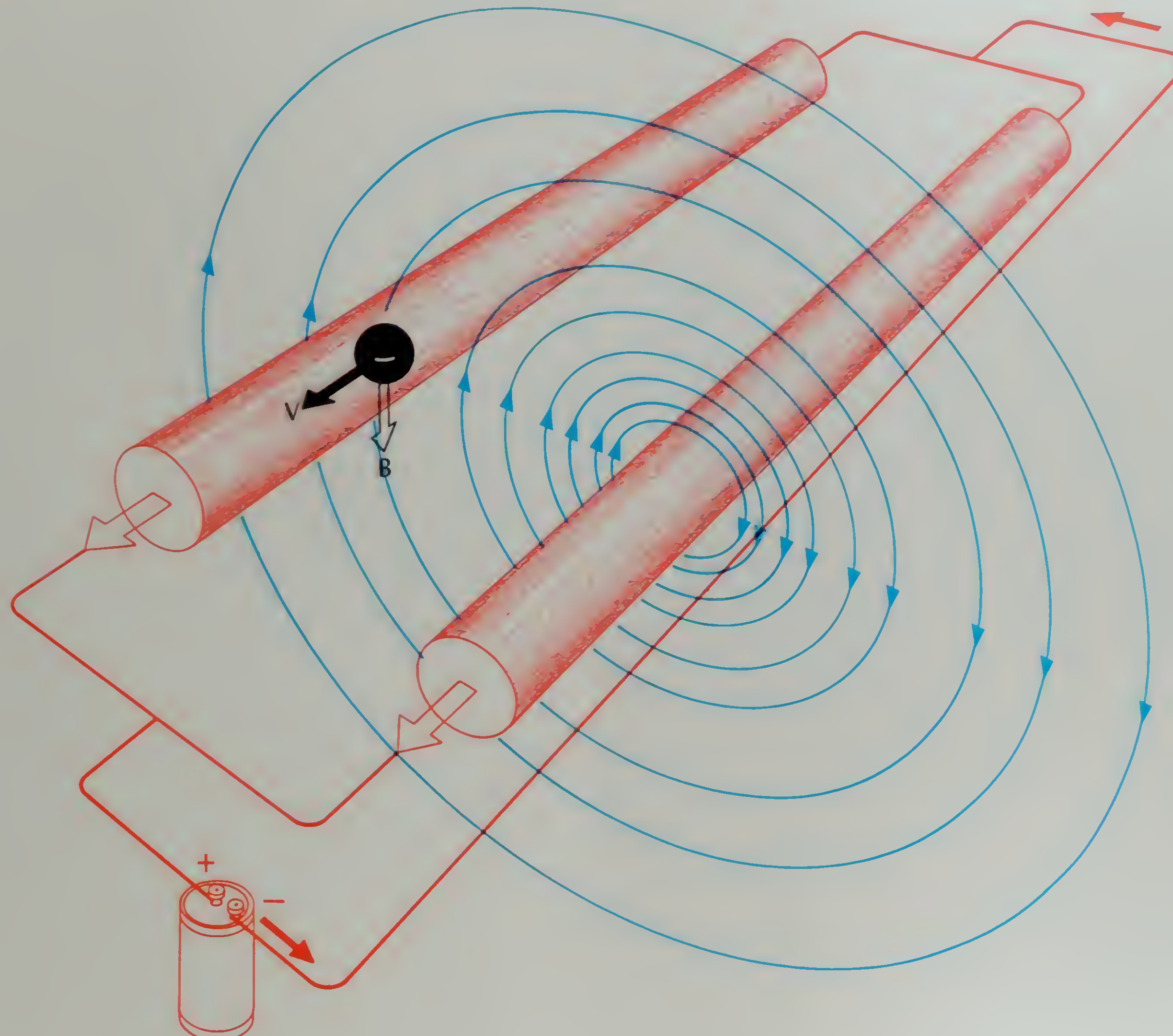
E

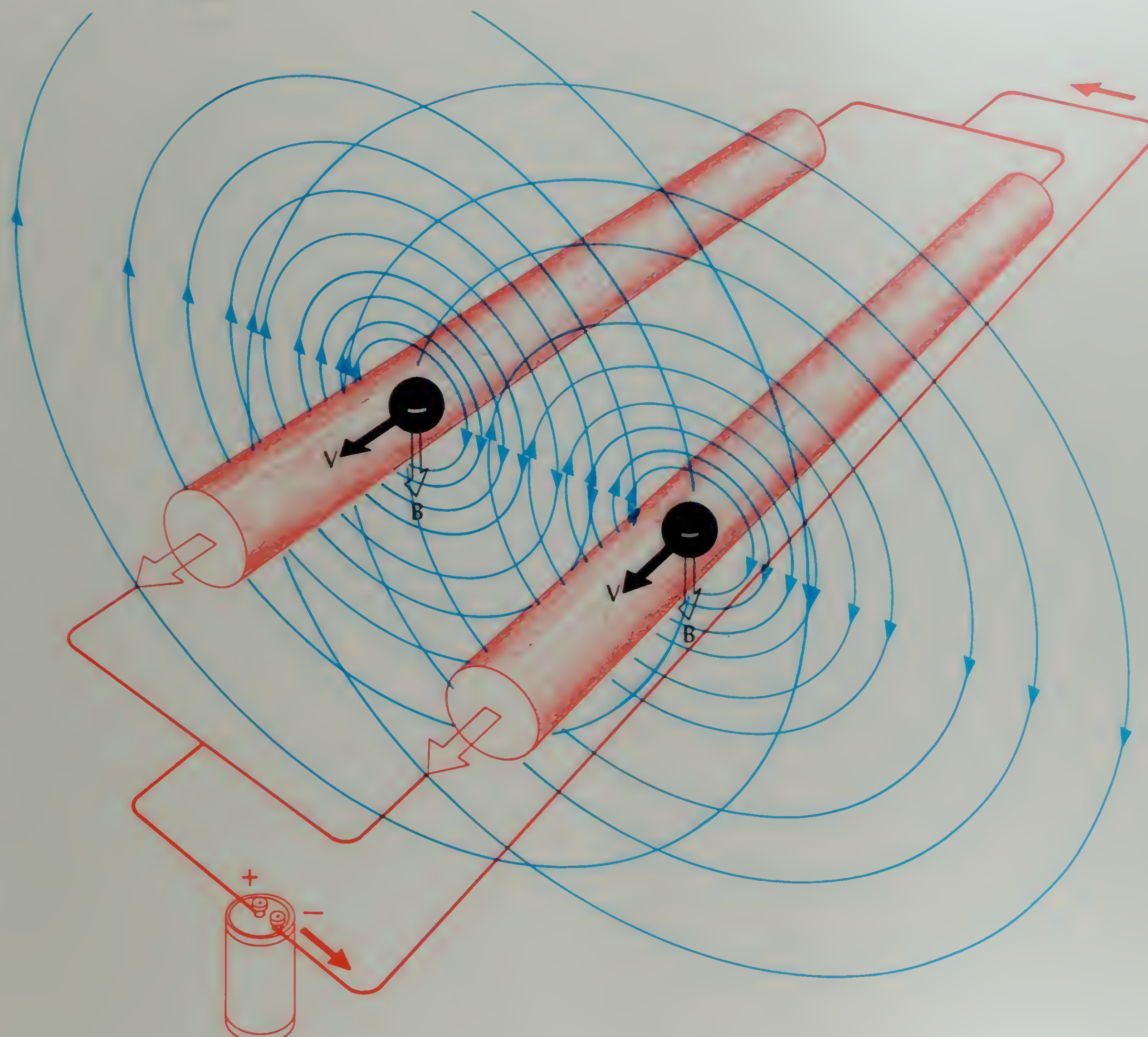


A F

E

A
G
E



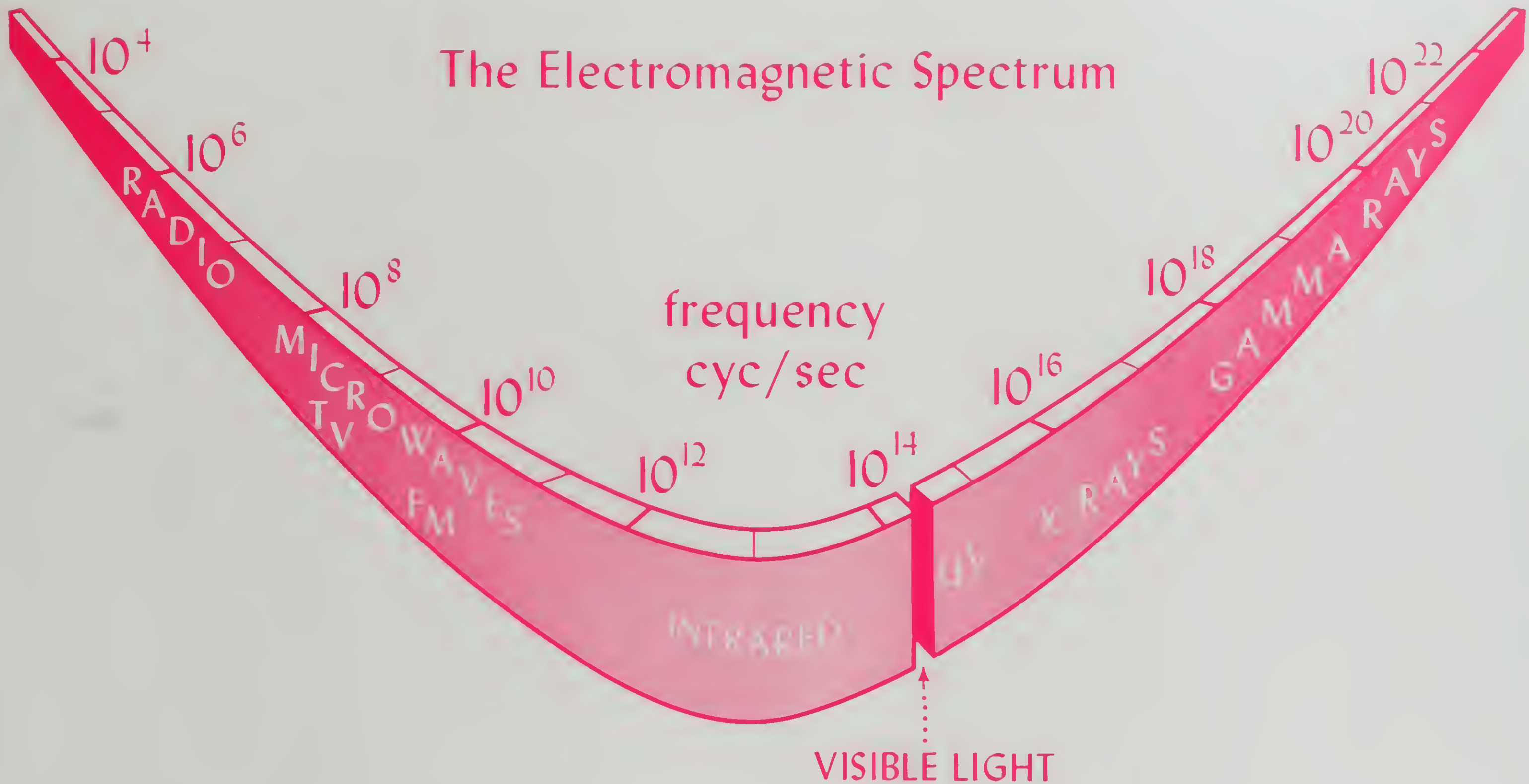

V
B
V
B
+
−
F
G
E

The Electromagnetic Spectrum

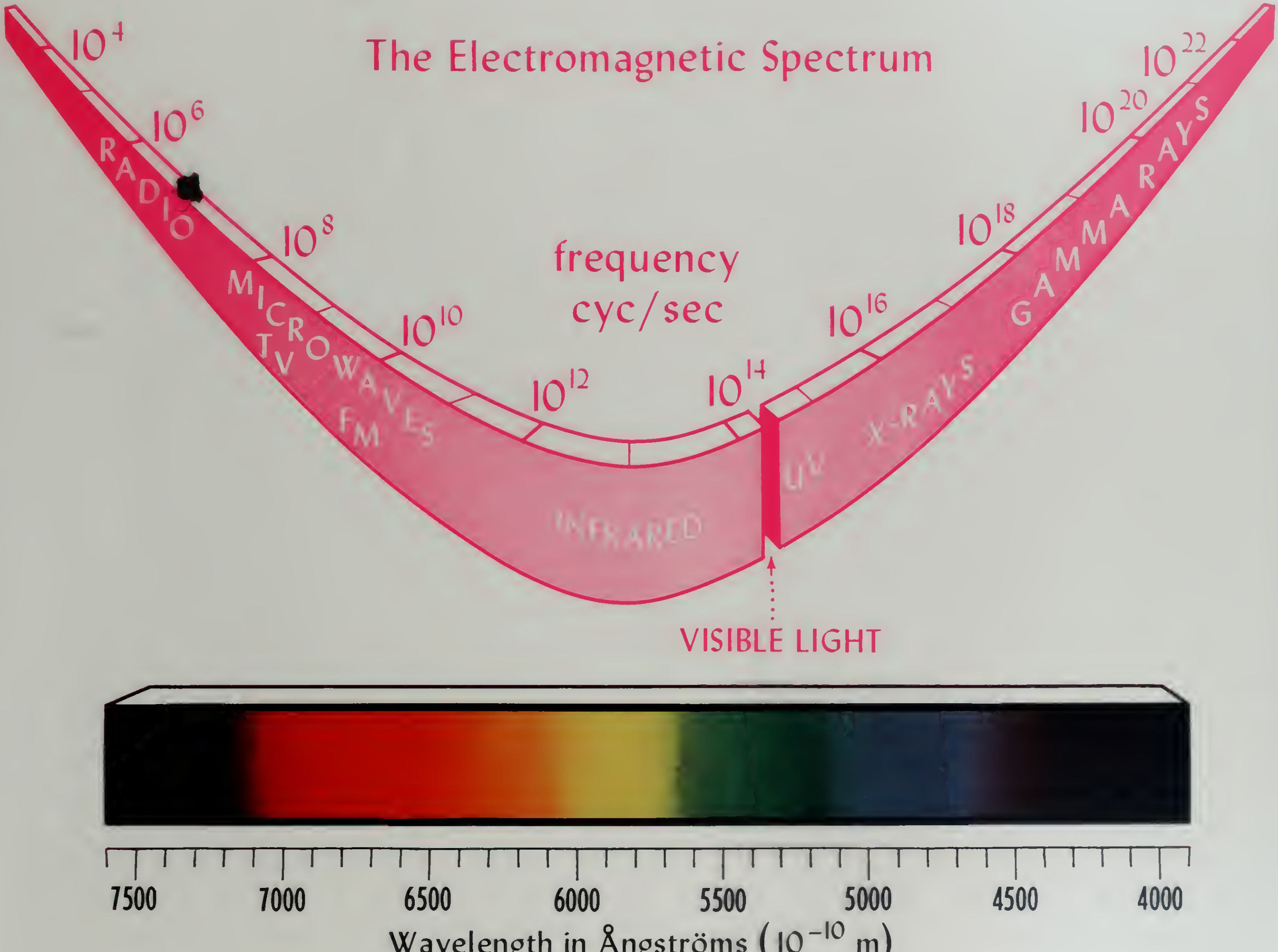
The Electromagnetic Spectrum

This transparency may be used extensively both in Unit 4 and in Unit 5. It presents a diagram of the continuum of the electromagnetic spectrum with a full color reproduction of the visible spectrum. In addition several spectra of elements are presented.

Overlay A	The full electromagnetic spectrum is shown in perspective with a missing slot representing the visible light segment.
Overlay B	The visible spectrum with an Ångström wavelength scale.
Overlay C	Some of the principal Fraunhofer lines in the solar spectrum. Remove this overlay and introduce each of the successive overlays separately.
Overlay D	The principal lines in the Hydrogen emission spectrum.
Overlay E	The principal lines in the Helium emission spectrum.
Overlay F	The principal lines in the Mercury emission spectrum.
Overlay G	The principal lines in the Sodium emission spectrum.
Overlay H	The principal lines in the Sodium absorption spectrum.

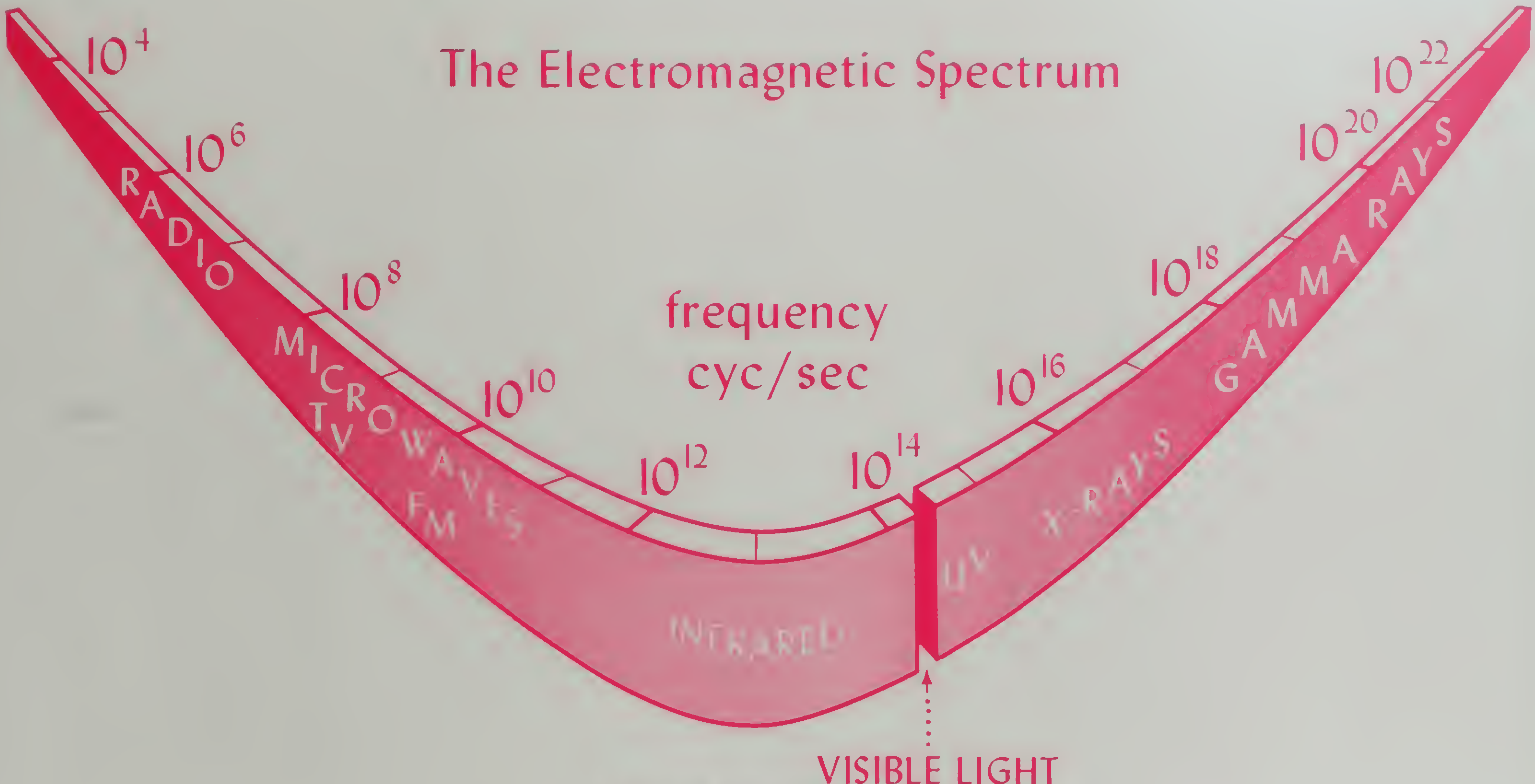

The Electromagnetic Spectrum
frequency cyc/sec
10^4
10^6
10^8
10^{10}
10^{12}
10^{14}
10^{16}
10^{18}
10^{20}
10^{22}
RADIO
MICROWAVES
TV
FM
INFRARED
UV
X RAYS
GAMMA RAYS
VISIBLE LIGHT

A
B

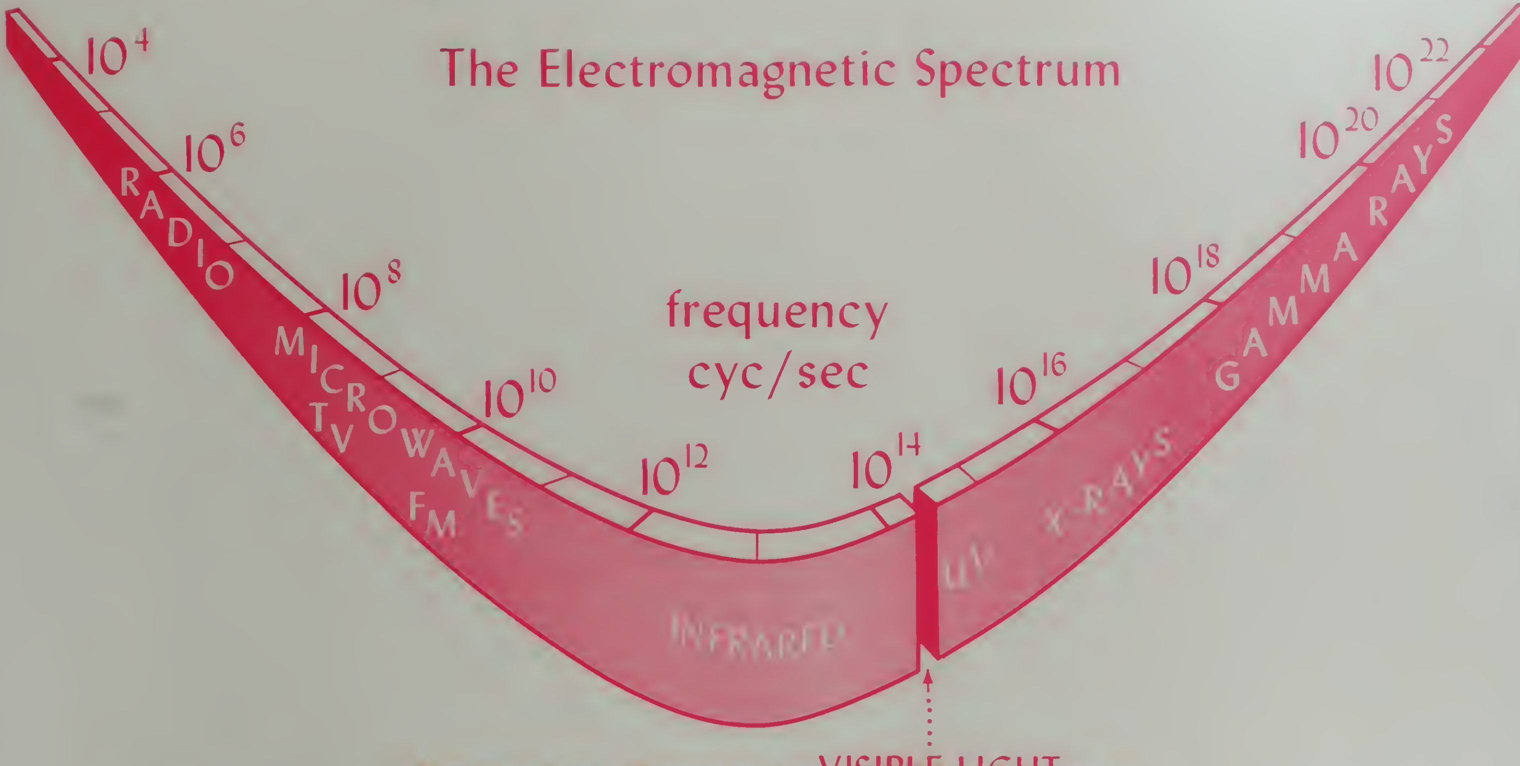

The Electromagnetic Spectrum
frequency
cyc/sec
10^4
10^6
10^8
10^{10}
10^{12}
10^{14}
10^{16}
10^{18}
10^{20}
10^{22}
RADIO
MICROWAVES
TV
FM
INFRARED
UV
X-RAYS
GAMMA RAYS
VISIBLE LIGHT
7500
7000
6500
6000
5500
5000
4500
4000
Wavelength in Ångströms (10^{-10} m)

A

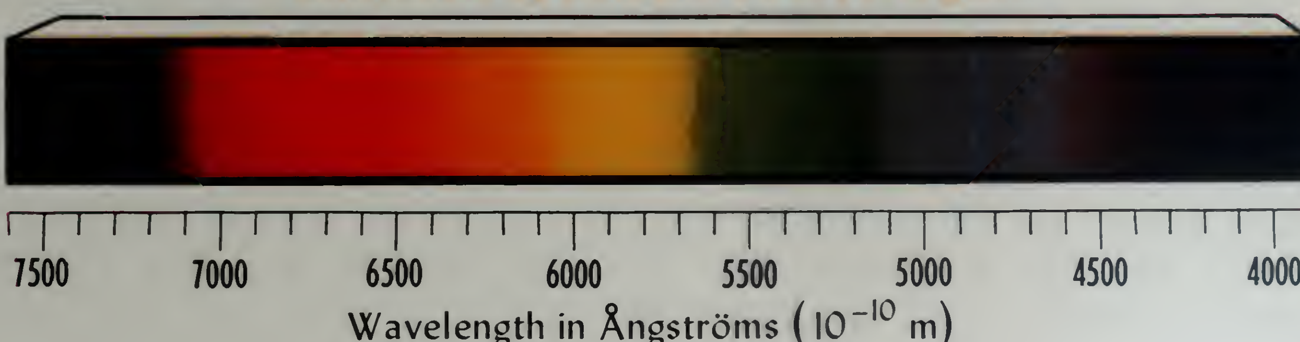
C

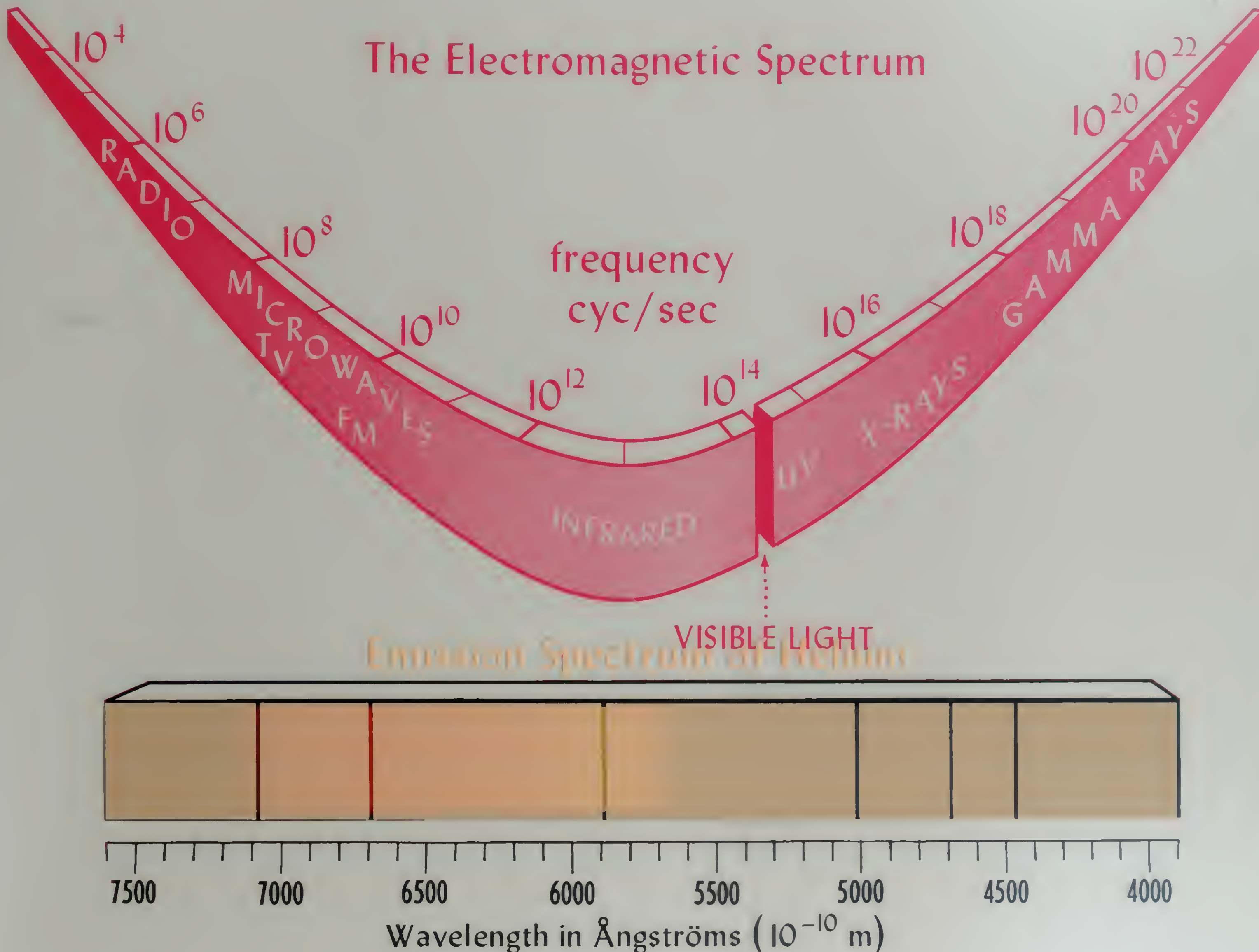


Fraunhofer Lines



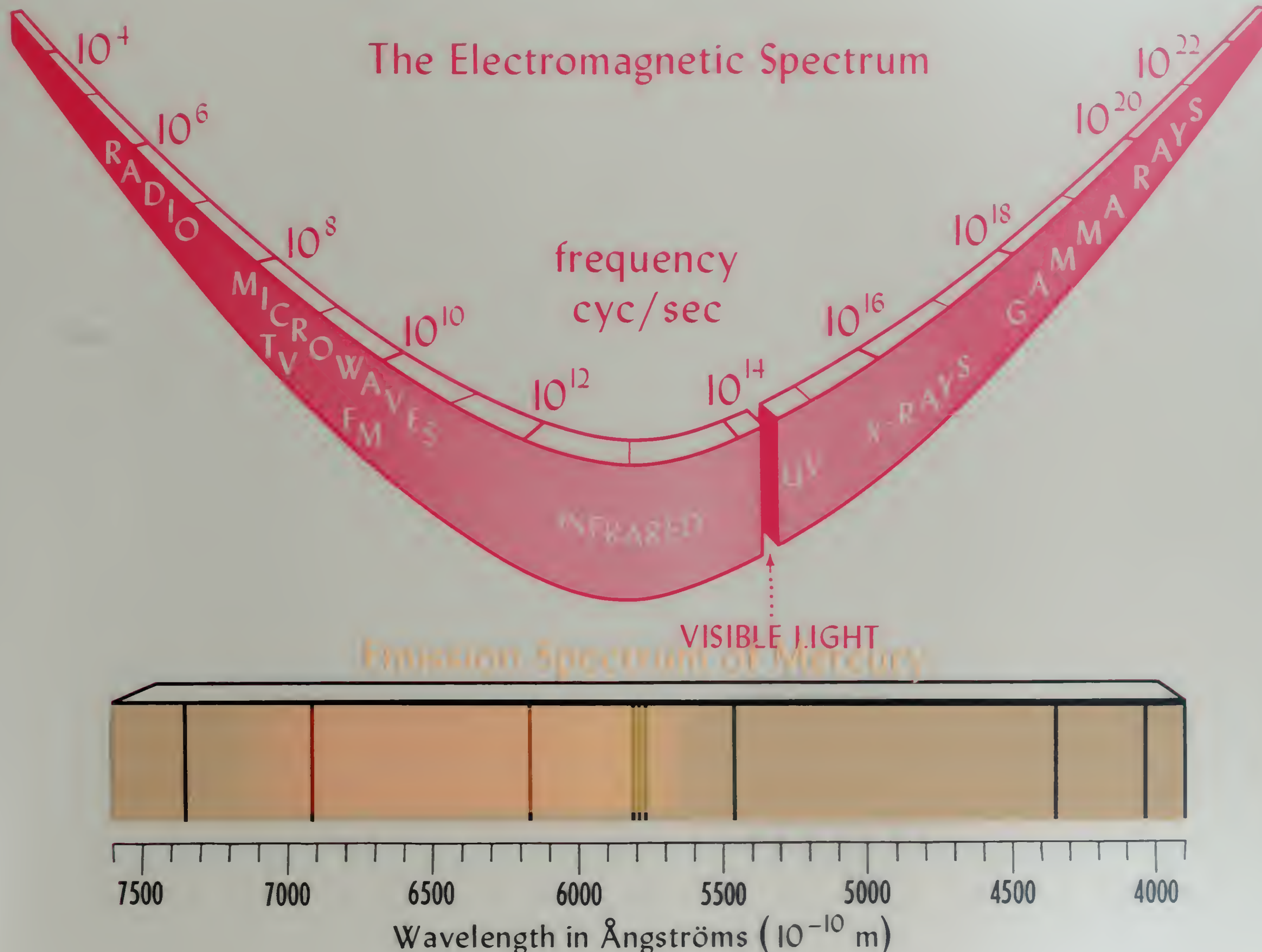
Emission Spectrum of Hydrogen





The Electromagnetic Spectrum
frequency
cyc/sec
10^4
10^6
10^8
10^{10}
10^{12}
10^{14}
10^{16}
10^{18}
10^{20}
10^{22}
RADIO
MICROWAVES
TV
FM
INFRARED
UV
X-RAYS
GAMMA RAYS
VISIBLE LIGHT
Emission Spectrum of Helium
7500
7000
6500
6000
5500
5000
4500
4000
Wavelength in Ångströms (10^{-10} m)

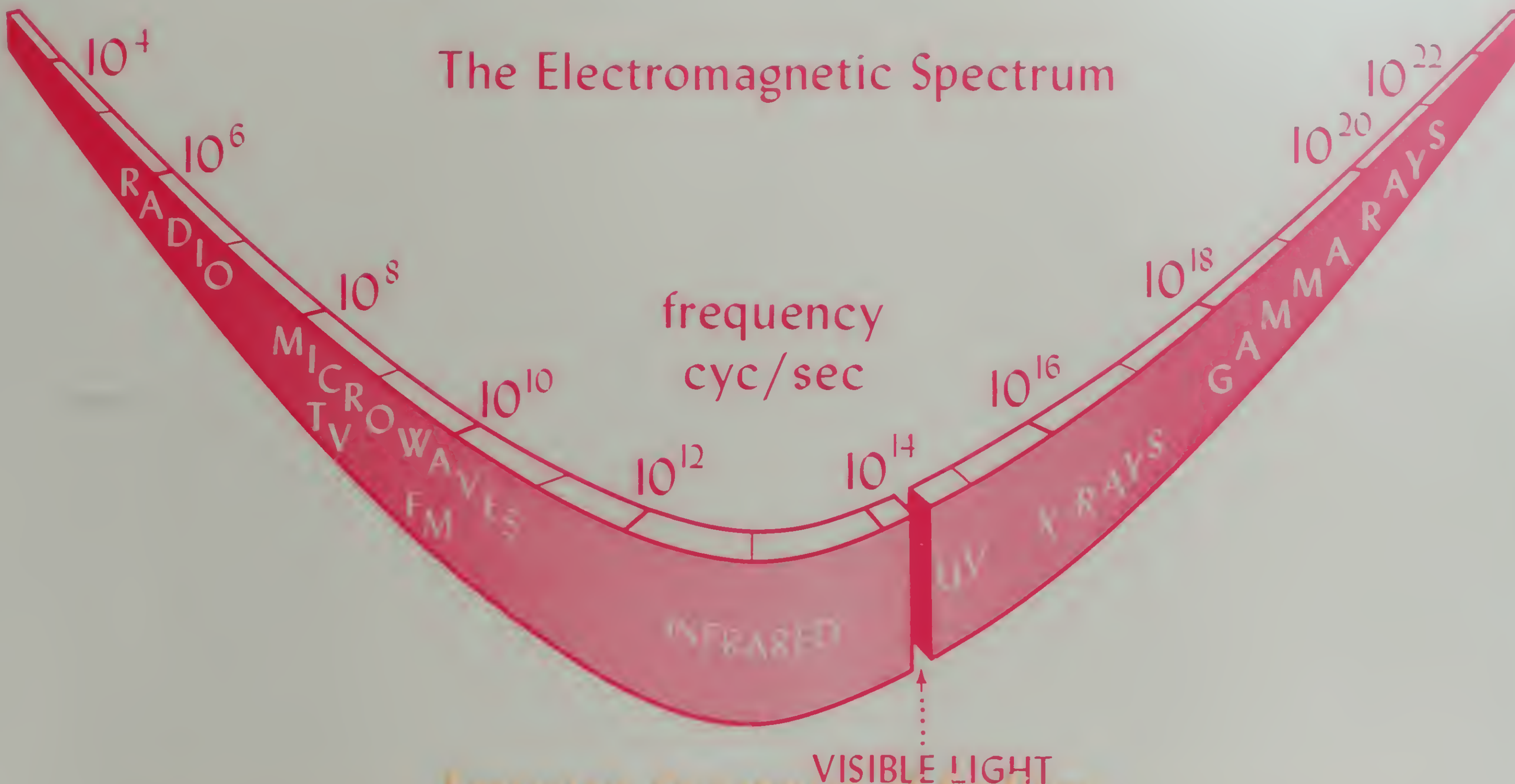
T34

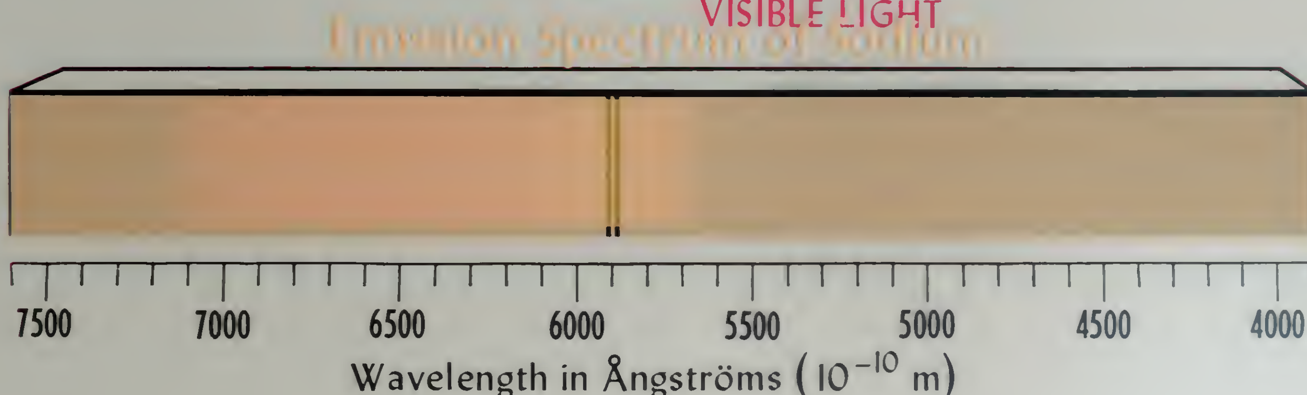


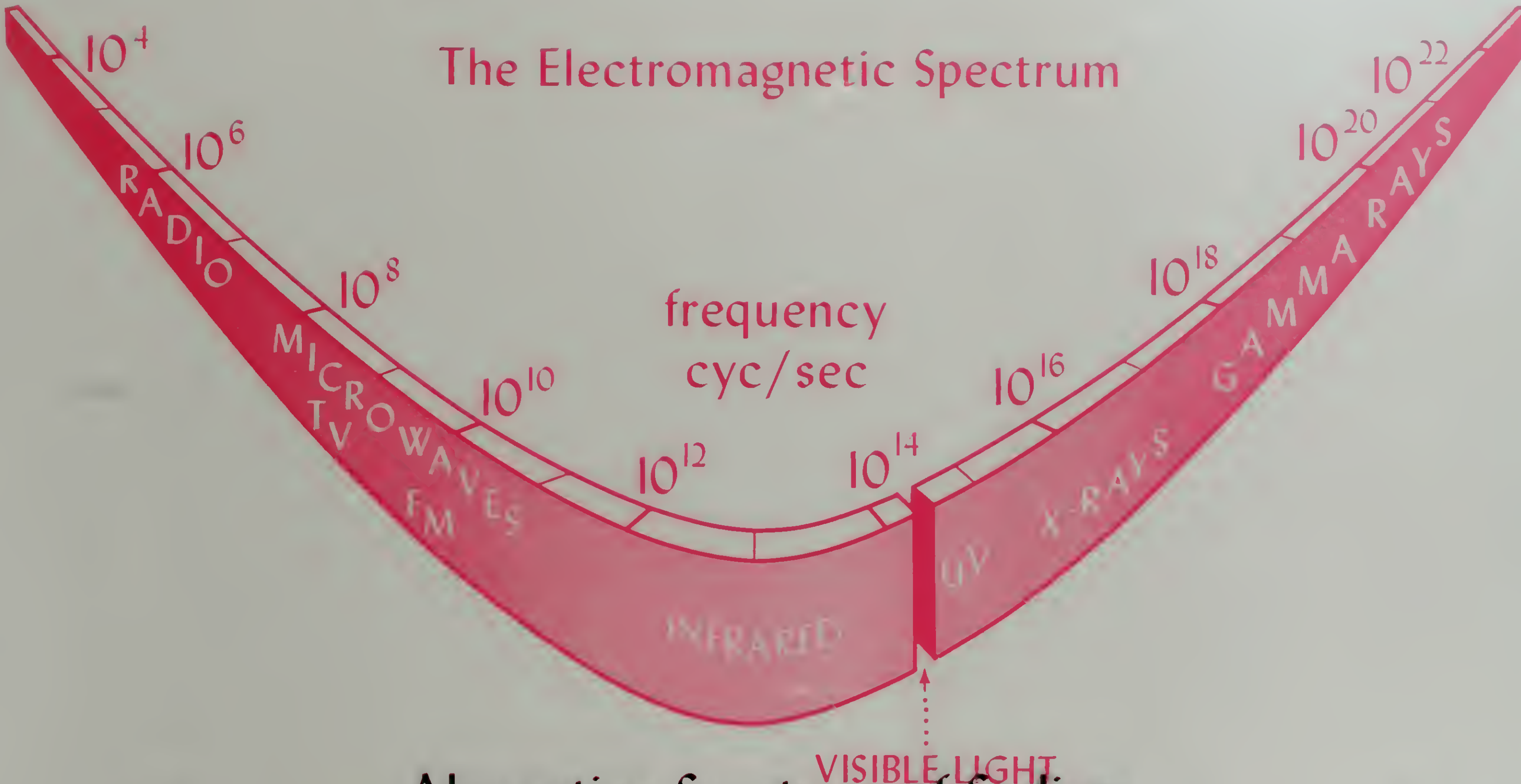
The Electromagnetic Spectrum
frequency
cyc/sec
10^4
10^6
10^8
10^{10}
10^{12}
10^{14}
10^{16}
10^{18}
10^{20}
10^{22}
RADIO
MICROWAVES
TV
FM
INFRARED
UV
X-RAYS
GAMMA RAYS
VISIBLE LIGHT
Emission Spectrum of Mercury
7500
7000
6500
6000
5500
5000
4500
4000
Wavelength in Ångströms (10^{-10} m)

A
B

A
B


The Electromagnetic Spectrum
frequency
cyc/sec
10^4
10^6
10^8
10^{10}
10^{12}
10^{14}
10^{16}
10^{18}
10^{20}
10^{22}
RADIO
MICROWAVES
TV
FM
INFRARED
UV
X RAYS
GAMMA RAYS
VISIBLE LIGHT


Emission Spectrum of Sodium
7500
7000
6500
6000
5500
5000
4500
4000
Wavelength in Ångströms (10^{-10} m)



Absorption Spectrum of Sodium