Chapter 9: Physical Nature of Light
End of Chapter Questions

1. What does a *changing magnetic field* induce?
2. What does a *changing electric field* induce?
3. What produces an electromagnetic wave?
4. What do electric and magnetic fields contain and transport?
5. What is light?
6. What is the principal difference between a *radio wave* and *light*?
7. What is the principal difference between *light* and an *X ray*?
8. How much of the measured electromagnetic spectrum does light occupy?
9. What color does visible light of the lowest frequencies appear? Of the highest?
10. How does the frequency of a radio wave compare to the frequency of the vibrating electrons that produce it?
11. How is the wavelength of light related to its frequency?
12. What is the wavelength of a wave that has a frequency of 1 Hz and travels at 300,000 km/s?
13. In what sense do we say that outer space is not really empty?
14. In about 1675 the Danish astronomer Olaf Roemer, measuring the times when one of Jupiter's moons appeared from behind Jupiter in its successive trips around that planet, and noticing the delays in these appearances as the earth got farther from Jupiter, is said to have concluded that light took an extra 16.5 minutes to travel 300,000,000 km across the diameter of the Earth's orbit around the sun. What approximate value for the speed of light is calculated from this data?
15. The sun is 1.50×10^{11} m from the Earth. How long does it take for the sun's light to reach the Earth?
16. How long does it take for a pulse of laser light to reach the moon and bounce back to Earth?
17. The nearest star beyond the sun is Alpha Centauri, 4.2×10^{16} meters away. If we received a radio message from this star today, how long ago would it have been sent?
18. The wavelength of yellow sodium light in air is 589 nm. What is its frequency?
19. Blue-green light has a frequency of about 6×10^{14} Hz. Find the wavelength of this light in air. How does this wavelength compare with the size of an atom, which is about 10^{-10} m?

Answers:

1. An electric field.
2. A magnetic field.
3. A vibrating electric charge, usually an electron.
4. Energy.
5. Light is energy-carrying waves of electric and magnetic fields that continually regenerate each other and travel at a single, fixed speed.
6. Frequency.
7. Frequency.
8. Less than a millionth of 1 percent.
9. Lowest is red; highest is violet.
10. Same.
11. The higher the frequency of the vibrating electron, the shorter the wavelength of light.
12. 300,000 km.
13. It is filled with electromagnetic radiation.
14. In seconds, this time is 16.5 min x 60 s = 990 s.
    Speed = $\frac{\text{distance}}{\text{time}}$ = 300,000,000 km/990 s = 303,030 km/s.
15. From $V = \frac{d}{t}$, $t = \frac{d}{v} = \frac{d}{c} = \frac{1.5x10^{11}m}{3x10^8 m/s}$ = 500 s (which equals 8.3 min).
    The time to cross the diameter of the Earth's orbit is twice this, or 1000 s, about 24% less than the 1,320 s measured by Roemer.
16. Earth-moon distance is 3.8 x 10^8 m, so the round-trip distance is 7.6 x 10^8 m. As in the previous problem, $\mathbf{t = \frac{d}{v} = \frac{7.6x10^8 m}{3x10^8 m/s} = 2.5\ s.}$
    (In 1969, when TV showed astronauts first landing on the moon, people in their living rooms could listen in on conversations between the astronauts and "Earthlings" and directly perceive the time delay. In 1675 Roemer saw the effect of light's finite speed "with his own eyes." Nearly 300 years later, millions of people heard the effect of the finite speed of electromagnetic waves "with their own ears.")
17. As in the previous problem, *t* = $t = \frac{d}{v} = \frac{4.2x10^{16}m}{3x10^8 m/s} = \mathbf{1.4x10^8\ s.}$ = 1.4 x 10^8 s.
    Converting to years by dimensional analysis,
    1.4 x 10^8 s x $\frac{1h}{3600s} \times \frac{1day}{24h} \times \frac{1yr}{365day} = \mathbf{4.4\ yr.}$
18. Wavelength 589 nm = 589 x 10^{-9}m = 5.89 x 10^{-7} m. From *c = f?* , *f = c/?* = (3 x 10^8m/s)/(5.89 x 10^{-7} m) = 5.09 x 10^{14} Hz.
19. From speed = *frequency x wavelength*, wavelength = speed / frequency = 5 x 10^{-7} m, or 500 nanometers. This is 5000 times larger than the size of an atom, which is 0.1 nanometer.