Chapter 24 Electromagnetic Waves

24.1 The nature of electromagnetic waves
1. Which one of the following will not generate electromagnetic waves or pulses?
   a. A steady direct current
   b. An accelerating electron
   c. A proton in simple harmonic motion
   d. An alternating current
   e. Charged particles traveling in a circular path in a mass spectrometer

24.2 The electromagnetic spectrum
   \( c = f \lambda \)
2. Which one of the following types of wave is intrinsically different from the other four?
   a. Radio waves
   b. Sound waves
   c. Gamma rays
   d. Ultraviolet radiation
   e. Visible light

3. Complete the following sentence: Ther various colors of visible light differ in
   a. Frequency only.
   b. Wavelength only
   c. Their speeds in a vacuum.
   d. Frequency and wavelength

4. Which one of the following colors of visible light has the highest frequency?
   a. Yellow
   b. Red
   c. Green
   d. Blue
   e. Violet

5. When a radio telescope observes a region of space between two stars, it detects
   electromagnetic radiation that has a wavelength of 0.21 m. This radiation was
   emitted by hydrogen atoms in the gas and dust located in that region. What is the
   frequency of this radiation?
   a. 1.4×10^{9} Hz

6. An FM radio station generates radio waves that have a frequency of 95.5 MHz. The
   frequency of the waves from a competing station have a frequency of 102.7 MHz.
   What is the difference in wavelength between the waves emitted from the two
   stations?
   a. 0.220 m

24.3 The speed of light
   \[ c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = 2.9979 \times 10^8 \text{ m/s} = \frac{\Delta x}{\Delta t} \]
7. A radio wave sent from the earth’s surface reflects from the surface of the
   moon and returns to the earth. The elapsed time between the generation of the
wave and the detection of the reflected wave is 2.6444 s. Determine the
distance form the surface of the earth to the surface of the moon.
a. 3.9638×10^8 m

8. A distant space probe is programmed to emit a radio signal toward Earth at
regular time intervals. One such pulse arrives on Earth 2.92 s after it is
emitted from the probe. What is the approximate distance from the Earth to
the probe?
a. 8.76×10^8 m

9. A cellular telephone transmits electromagnetic waves at a frequency of 935
MHz. What is the wavelength of these waves?
a. 0.321 m

24.4 The energy carried by electromagnetic waves

\[ E = cB \]
\[ S = \frac{1}{2} \left( \varepsilon_0 E^2 + \mu_0 B^2 \right) \]

10. The amplitude of the electric field component of an electromagnetic wave is
increased from E to 4E. What is the corresponding change in the intensity of
the wave?
a. The intensity increases by a factor of sixteen.

11. The peak value of the electric field component of an electromagnetic wave is
E. At a particular instant, the intensity of the wave is of 0.020 W/m^2. If the
electric field were increased to 5E, what would be the intensity of the wave?
a. 0.50 W/m^2

24.5 The Doppler Effect and Electromagnetic Waves

Not really covered

24.6 Polarization

\[ S_1 = \frac{1}{2} S_o, \quad S_\hat{n} = S_n \left( \cos \theta_{n-(n-1)} \right)^2 \]

12. Initially unpolarized light of intensity \( S_o \) passes through two sheets of
polarizing material whose transmission axes make an angle of 60° with each
other. What is the intensity of the transmitted beam?
a. \( S_o / 8 \)

13. Linearly polarized light is incident on a sheet of polarizing material. The angle
between the transmission axis and the incident electric field is 52°. What
percentage of the incident intensity is transmitted?
a. 38%

Chapter 25 The Reflection of Light: Mirrors

25.1 Wave Fronts and Rays

14. For a star, radiating light uniformly in all directions, represent the radiated
light with both rays and wavefronts.

25.2 The Reflection of Light

\[ \theta_r = \theta_i \]

15. A ray of light is reflected from two plane mirror surfaces as shown in
the figure. What are the correct values of the angles \( \alpha \) and \( \beta \)?
a. \( \alpha = 26° \quad \beta = 64° \)
25.3 **The Formation of Images by a plane mirror**

16. An object is placed 1 m in front of a plane mirror. An observer stands 3 m behind the object. For what distance must the observer focus his eyes in order to see the image of the object?
   a. 5 m

25.4 **Spherical Mirrors**

\[
f = \frac{1}{2} R
\]

17. The focal length of a spherical concave mirror is 20 cm. What is its radius of curvature?
   a. 40 cm

18. A concave mirror has a radius of curvature of 30 cm. How close to the mirror should an object be placed so that the rays travel parallel to each other after reflection?
   a. 15 cm

25.5 **The Formation of Images By Spherical Mirrors**

19. Santa Claus looks at his reflection in a spherical Christmas tree ornament. Which one of the following statements concerning Santa’s image is true?
   a. The image must be real.
   b. The image is farther from the ornament than Santa is.
   c. The image is larger than Santa.
   d. The image must be inverted.
   e. **The image must be smaller than Santa.**

20. Complete the ray diagram to indicate location, sized, and orientation of the image relative to the object. Is the image real or virtual?

21. How about for this set-up?
25.6 The Mirror Equation and The Magnification Equation

\[ m = \frac{h_i}{h_o} = -\frac{d_i}{d_o} \]

\[ \frac{1}{d_o} + \frac{1}{\pm d_i} = \frac{1}{\pm f} \]

22. In the above picture, say the object is 4.00 m from the mirror surface, and the mirror has a 3.00 m radius of curvature. How far is the image from the mirror surface?
   a. 1.09 m

Chapter 26 The Refraction of Light: Lenses and Optical Instruments

26.1 The Index of Refraction

\[ n_x = \frac{c}{v_x} \]

23. The bending of light as it moves from one medium to another with different indices of refraction is due to a change in what property of the light?
   a. Amplitude  c. frequency  e. color
   b. Period  d. speed

24. When certain light rays pass from a vacuum into a block of an unknown material, the measured index of refraction of the material is 3.50. What is the speed of light inside the block?
   a. 8.6×10⁷ m/s

26.2 Snell's Law and the Refraction of Light

\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]

25. A scuba diver shines a flashlight from beneath the surface of water ( n = 1.33) such that the light strikes the water-air boundary with at 47° measured up from the water surface. At what angle is the beam refracted, as measured down from the surface?
   a. 65°

26. A ray of light propagates in water (n=1.333) and strikes a sheet of crown glass ( n = 1.523). If the angle of refraction in the glass is 35.2°, measured off the normal to the interface, determine the angle of incidence, measured off the normal to the interface.
   a. 41.2°

26.3 Total Internal Reflection
\[ \sin \theta_c = \frac{n_2}{n_1}, n_1 > n_2 \]

27. A light ray is traveling in a diamond \((n=2.419)\). If the ray approaches the diamond-air interface, what is the minimum angle of incidence that will result in all of the light being reflected back into the diamond? The index of refraction for air is 1.000.
   a. 24.42°

26.5 The Dispersion of Light: Prisms and Rainbows
Only qualitatively

26.6 Lenses

26.7 The formation of images by lenses
28. An object is placed at the focal point of a converging lens of focal length \(f\), what is the image distance?
   a. infinity

29. Trace some representative rays to determine the image’s location, size, and orientation. Is it real or virtual?

\[ \text{Object} \rightarrow \text{Lense} \rightarrow \text{Image} \]

26.8 The thin-lens equation and the magnification equation
\[ m = \frac{h_i}{h_o} = \frac{-d_i}{d_o} \]
\[ \frac{1}{\pm d_o} + \frac{1}{\pm d_i} = \frac{1}{\pm f} \]

30. Say the object is 4.0 cm from the converging lens whose focal length is 1.2 cm. How far is the image form the lens?
   a. 1.7 cm

31. What is the magnification?
   a. -.425

26.9 Lenses in Combination
Only as far as we got in lab
\[ \frac{1}{f_{1,2}} = \frac{1}{f_1} + \frac{1}{f_2} \]

Chapter 27 Interference and the wave nature of light

27.1 The principle of linear superposition
27.2  Young’s Double-slit experiment

$$\sin \theta_{con} = m \frac{\lambda}{d}, \ m = 0,1,2,...$$

$$\sin \theta_{de} = (m + \frac{1}{2}) \frac{\lambda}{d}, \ m = 0,1,2,...$$

32.  Two identical light waves, A and B, are emitted from different sources and meet at a point P. The distance from the source of A to point P is $l_A$; and the source of B is a distance $l_B$ form P. Which of the following statements is necessarily true concerning the interference of the two waves?

a.  A and B will interfere constructively because their amplitudes are the same.

b.  A and B will interfere constructively if $l_A = l_B$.

c.  A and B will interfere destructively if $l_A - l_B = m\lambda$ where $m = 0, 1,2,3,...$

d.  A and B will interfere destructively if $l_A$ is not equal to $l_B$.

e.  A and B will interfere constructively because their wavelengths are the same.

33.  A double slit is illuminated with monochromatic light of wavelength 600 nm. The $m = 0$ and $m = 1$ bright fringes are separated by 3.0 cm on a screen which is located 4.0 m from the slits. What is the separation between the slits?

a.  $8.0 \times 10^{-5}$ m

34.  Two slits separated by $2.00 \times 10^{-5}$ m are illuminated by light of wavelength 500 nm. If the screen is 8.00 m from the slits, what is the distance between $m = 0$ and $m = 1$ bright fringes?

a.  20.0 cm

27.3  Thin-Film Interference

$$t_s = m \frac{\lambda_s}{2}, \ m = 1,2,3,...$$

$$\lambda_s = \frac{\lambda_{vac}}{n_s}$$

35.  To measure the thickness of a thin film of soap ($n=1.40$) floating on water ($n=1.33$), light is reflected from the film. Strong destructive interference occurs when green light ($\lambda = 500.0$ nm in vacuum) is used and the reflected beam is very dim. Determine the two smallest, non-zero thickness’ for the soap film.

a.  179 nm, 357 nm

27.5  Diffraction

$$\sin \theta_{de} = m \frac{\lambda}{W}, \ m = 1,2,...$$

36.  Light of 600.0 nm is incident on a single slit of width $6.5 \times 10^{-6}$ m. The resulting diffraction pattern is observed on a nearby screen and has a central maximum of width 3.5 m. What is the distance between the screen and the slit?

a.  19.0 m
37. Light of wavelength 600 nm is incident upon a single slot with width $4 \times 10^{-4}$ m. The figure shows the pattern observed on a screen positioned 2 m from the slits. Determine the distance $S$.

![Pattern diagram]

\[ a. \quad 0.006 \text{ m} \]

38. Light with a wavelength of 644 nm uniformly illuminates a single slit. What is the width of the slit if the first-order dark fringe is located at $\theta = 0.125^\circ$?

\[ a. \quad 2.95 \times 10^{-4} \text{ m} \]

Chapter 28 Special Relativity

28.1 Events and Inertial Reference Frames

39. At time $t = 2.3 \, \text{s}$, a 4-kg block that initially moves with a constant speed of 6 m/s undergoes an inelastic collision with another block. Any two inertial observers must agree that

a. The event took place at $t = 2.3 \, \text{s}$.

b. The initial speed of the block is 6 m/s.

c. The initial momentum of the block has magnitude 24 kg m/s.

d. The second block is moving after the collision.

e. The momentum of the two block system is conserved during the collision.

28.2 The Postulates of Special Relativity

28.3 The Relativity of Time: Time Dilation

\[ \Delta t = \frac{\Delta t_o}{\sqrt{1 - \left(\frac{v}{c}\right)^2}} \]

40. Which one of the following statements concerning the proper time interval between two events is true?

a. It is the longest time interval that any inertial observer can measure for the event.

b. **It is the shortest time interval that any inertial observer can measure for the event.**

c. It is the time measured by an observer who is in motion with respect to the event.

d. Its value depends upon the speed of the observer.

e. Its value depends upon the choice of reference frame.

41. In the year 2100, an astronaut wears an antique, but accurate, “quartz” wristwatch on a journey at a speed of $2.0 \times 10^8 \, \text{m/s}$. According to mission control in Houston, the trip lasts 12 hours. How long was the trip as measured on the watch?

\[ a. \quad 8.9 \, \text{hrs} \]
42. During a baseball game, a batter hits a ball directly back to the pitcher who catches it. An observer flying over the stadium at a speed of 0.75c, measures 0.658s as the time between the hit and the catch. What is the proper time interval between the two events?
   a. 0.435 s

28.4 The Relativity of Length: Length Contraction

\[ L = L_o \sqrt{1 - \left( \frac{v}{c} \right)^2} \]

43. Which one of the following statements concerning the proper length of a meter stick is true?
   a. The proper length is always one meter.
   b. The proper length depends upon the speed of the observer.
   c. The proper length depends upon the acceleration of the observer.
   d. The proper length depends upon the reference frame in which it is measured.
   e. The proper length is the length measured by an observer who is moving with respect to the meter stick.

44. A UFO flies directly over the length of a football stadium at a speed of 0.5c. If the proper length of the field is 100 yards, what field length is measured by the pilot of the UFO?
   a. 87 yards

28.5 Relativistic Momentum

\[ p = m \frac{\Delta x}{\Delta t_o} = \frac{mv}{\sqrt{1 - \left( \frac{v}{c} \right)^2}} \]

45. A proton has a mass of 1.673 \times 10^{-27} kg. If the proton is accelerated to a speed of 0.93c, what is the magnitude of the relativistic momentum of the proton?
   a. 1.3\times10^{-18} \text{ kg m/s}

46. In the distant future, a 5.40\times10^5 kg intergalactic ship leaves Earth orbit and accelerates to a constant speed of 0.92c. Determine the difference, \(p - p_o\), between the relativistic and classical momenta of the ship.
   a. 2.3\times10^{14} \text{ kg m/s}

28.6 The Equivalence of Mass and Energy

\[ E = \frac{mc^2}{\sqrt{1 - \left( \frac{v}{c} \right)^2}} \]

47. Determine the total energy of an electron traveling at 0.98 c.
   a. 2.6 MeV

48. How much energy would be released if 0.001 kg of material were completely converted into energy?
   a. 9\times10^{13} \text{ J}
49. A subatomic particle X spontaneously decays into two particles, A and B, each with rest energy 140 MeV. The particles fly off in opposite directions, each with speed 0.827c relative to an observer in an inertial reference frame. Determine the total energy of particle A.
   a. 249 MeV

28.7 The Relativistic Addition of Velocities

\[ v_{AB} = \frac{v_{AC} + v_{CB}}{1 + \frac{v_{AC}v_{CB}}{c^2}} \]

50. Two spaceships are observed from Earth to be approaching each other along a straight line. Ship A moves at 0.40c relative to the Earth observer, while ship B moves at 0.50c relative to the same observer. What speed does the captain of ship A report for the speed of ship B?
   a. 0.75c

51. An Earth observer sees and alien ship pass overhead at 0.3c. The ion gun of the ship shoots ions straight ahead of the ship at a speed of 0.4c relative to the ship. What is the speed of the ions relative to the Earth observer?
   a. 0.63c

Chapter 29 Particles and Waves

29.1 The Wave-Particle Duality

29.2 Blackbody Radiation and Plank’s Constant

\[ E_{ph} = hf \]

\[ h = 6.62606891 \times 10^{-34} \text{ J s} \]

29.3 Photons and The Photoelectric Effect

\[ E_{ph} = KE_{\text{max}} + W_o \]

52. Upon which one of the following parameters does the energy of a photon depend?
   a. Mass  c. polarization  e. phase relationships
   b. Amplitude  d. frequency

53. Determine the energy of a single photon in a beam of light of wavelength 450 nm.
   a. 2.8 eV

54. A laser emits photons of energy 2.5 eV with a power of 10^{-3} W. How many photons are emitted in one second?
   a. 2.5\times10^{15}

55. Complete the following statement: The photon description of light is necessary to explain
   a. Polarization  c. diffraction  e. interference
   b. Photoelectric effect

56. Which type of wave motion does not involve photons?
   a. Gamma rays  c. radio waves  e. sound waves
   b. Microwaves  d. infrared radiation

57. Photons with what minimum frequency are required to remove electrons from gold, whose work function is 4.8 eV?
   a. 1.16\times10^{15} \text{ Hz}
29.4 The Momentum of a Photon and the Compton Effect

\[ hf = hf' + KE \]
\[ \frac{h}{\lambda} = \frac{h}{\lambda'} + m_e v \]
\[ \lambda' - \lambda = \frac{h}{mc} (1 - \cos \theta) \]

58. A digital wireless telephone communicates via microwaves that have a frequency of 1930 MHz. What are the momentum and energy for the microwave photons emitted by the telephone?
   a. Momentum = \(4.27 \times 10^{-33}\) kg m/s, Energy = \(1.28 \times 10^{-24}\) J

59. In the Compton effect, a photon of wavelength \(\lambda\) and frequency \(f\) hits an electron that is initially at rest. Which one of the following occurs as a result of the collision?
   a. The photon is absorbed completely.
   b. The photon gains energy, so the final photon has a frequency greater than \(f\).
   c. The photon gains energy, so the final photon has a wavelength greater than \(\lambda\).
   d. The photon loses energy, so the final photon has a frequency less than \(f\).
   e. The photon loses energy, so the final photon has a wavelength less than \(\lambda\).

60. In a Compton scattering experiment, a beam of X-ray light strikes a target. The light which scatters at an angle 45° has a wavelength of \(2.50 \times 10^{-12}\) m. Given that the mass of an electron is \(9.11 \times 10^{-31}\) kg, what is the wavelength of the incident X-rays?
   a. \(1.79 \times 10^{-12}\) m

29.5 The De Broglie Wavelength and the Wave Nature of Matter

\[ p = \frac{h}{\lambda} \]

61. What kinetic energy must a beam of neutrons have if their wavelength is 0.10 nm? The mass of a neutron is \(1.67 \times 10^{-27}\) kg.
   a. \(1.3 \times 10^{-20}\) J

62. Determine the de Broglie wavelength of a neutron (\(m = 1.67 \times 10^{-27}\) kg) with a speed of 5.0 m/s.
   a. 79 nm

63. The Hubble Space Telescope has an orbital speed of \(7.56 \times 10^3\) m/s and a mass of 11,600 kg. What is its de Broglie wavelength?
   a. \(7.56 \times 10^{-42}\) m

Chapter 30 The Nature of the Atom
(We did not follow the book’s development of this material; see lecture notes)

30.1 Rutherford Scattering and the Nuclear Atom

30.2 Line Spectra

30.3 The Bohr Model of the Hydrogen Atom

\[ r_n = \frac{1}{mkZ} \left( \frac{hn}{2\pi e} \right)^2, \quad n = 1, 2, 3, \ldots \]

\[ E_n = -\frac{m}{2} \left( \frac{4\pi kZ e^2}{nh} \right)^2, \quad n = 1, 2, 3, \ldots \]
\[ E_{ph} = |E_{n,f} - E_{n,i}| \]

64. Each atom in the periodic table has a unique set of spectral lines. Which one of the following statements is that best explanation for this observation?
   a. Each atom has a dense central nucleus.
   b. The electrons in atoms orbit the nucleus
   c. Each atom has a unique set of energy levels
   d. The electrons in atoms are in constant motion
   e. Each atom is composed of positive and negative charges.

65. Electrons have been removed from a beryllium atom (Z=4) until only one remains. Determine the energy of the photon that can be emitted if the remaining electron falls from the n = 2 level to the n = 1 level.
   a. 163 eV

66. Determine the wavelength of incident electromagnetic radiation required to cause an electron transition from the n = 6 to the n = 8 level in a hydrogen atom.
   a. \(7.5 \times 10^3\) nm

67. According to the Bohr model, what is the radius of a hydrogen atom when the electron is excited to the n = 9 state?
   a. \(4.28 \times 10^{-9}\) m

30.4 De Broglie’s Explanation of Bohr’s Assumption About Angular Momentum
\[ C = 2\pi r = n\lambda, n = 1,2,3... \]

Chapter 31 Nuclear Physics and Radioactivity

31.1 Nuclear Structure
\[ A = Z + N \]

68. How many neutrons are there in the nucleus \(^{205}_{85} Pb\)?
   a. 123

69. In which one of the following sets do the species have the same neutron number, N?
   a. \(^{16}_{8} O,^{14}_{7} N\)
   b. \(^{12}_{6} C,^{14}_{6} C\)
   c. \(^{16}_{8} O,^{23}_{11} Na\)
   d. \(^{14}_{7} N,^{13}_{6} C\)
   e. \(^{14}_{7} N,^{13}_{6} C\)

70. The nucleus of a certain isotope of tin contains 68 neutrons and 50 protons. What is its symbol?
   a. \(^{118}_{50} Sn\)

31.2 The Strong Nuclear Force and The Stability of the Nucleus

71. Which one of the following statements concerning stable nuclei is true?
   a. They all have nucleon numbers less than 83.
   b. They generally have odd atomic numbers
   c. They all have atomic numbers greater than 83
   d. They generally have an odd number of neutrons
   e. The generally have more neutrons than protons.
72. What interplay plays an important role in determining the N and Z numbers of stable nuclei?
   a. The balance between short range, strong attraction of the Strong Force and the long range, weaker repulsion of the Electric Force.

31.3 The Mass Defect of the Nucleus and Nuclear Binding Energy

\[ B.E. = \Delta P.E. = \Delta mc^2 = \left( \sum_{\text{parts}} m - m_{\text{whole}} \right) c^2 \]

73. The binding energy of an isotope of chloring is 298 MeV. What is the mass defect of this chlorine nucleus, in atomic mass units?
   a. 0.320 u

74. What is the mass defect of \(^{120}\text{Sn}\) (atomic mass = 119.902200 u)? The hydrogen atom has a mass of 1.00783 u; and the neutron has a mass of 1.00867 u
   a. \(6.9175 \times 10^{-28}\) kg

31.4 Radioactivity

\[ E_\gamma = -\Delta E \]

\[ \Delta K.E. = -\Delta P.E. = -\Delta mc^2 \]

75. Which kind of decay is illustrated by the reaction \(^{238}\text{Th} \rightarrow ^{234}\text{Ra} + ^4\text{He}\)?
   a. Alpha-decay

76. What particle(s) must be emitted when \(^{40}\text{K}\) decays into \(^{40}\text{Ca}\)?
   a. Electron and anti-neutrino

77. What isotope is produced when \(^{145}\text{Pm}\) alpha-decays?
   a. \(^{141}\text{Pr}\)

31.5 The Neutrino

31.6 Radioactive Decay and Activity

\[ N = N_0 e^{-\ln(2)/T_{1/2}} \]

\[ \frac{dN}{dt} = \left( -\frac{\ln(2)}{T_{1/2}} \right) N_0 e^{-\ln(2)/T_{1/2}} \]

reactivity = |dN/dt|

78. An isotope of krypton has a half-life of 3 minutes. A sample of this isotope produces 1000 counts per minute in a Geiger counter. Determine the number of counts per minute produced after 15 minutes.
   a. 30

79. What isotope is produced when \(^{214}\text{Bi}\) alpha decays?
a. \(^{210}\text{TI}\)

80. The half-life of a particular isotope of iodine is 8.0 days. How much of a 10.0g sample of this isotope will remain after 30 days?
   a. 0.74 g

81. The half-life of a particular barium isotope is 12 s. What is the activity of a \(10^{-6}\) kg sample of this isotope?
   a. \(2.4 \times 10^{17}\) decays/sec.

31.7 Radioactive Dating

\[ t = - \frac{T_X}{\ln(2)} \ln \left( \frac{T_X \cdot \frac{dN}{dt}}{\ln(2)N_o} \right) \]

82. Tritium is an isotope of hydrogen that has two neutrons in addition to its proton. Tritium undergoes \(\beta^-\) decay with a half-life of 12.3 years. What percentage of an initially pure sample of tritium will remain undecayed after 35 years?
   a. 14%

31.8 Radioactive Decay Series