PHYSICS III **The answers appear at the end of this document.**
Part 1: Light & Geometric Optics

1.1 Electromagnetic Waves

1) The following frequencies are for different types of electromagnetic radiation. Find the free-space wavelengths and the types of radiation. (a) 100 MHz (b) 480 THz (b) 2 GHz (d) $2x10^{20}$ Hz

2) A typical He-Ne laser emits 10 mW of power in a red beam with a diameter of 2 mm at a free-space wavelength of 632.8 nm. Find the following for the light: (a) frequency, (b) average intensity, (c) electric field amplitude, and (d) magnetic field amplitude.

3) A disc jockey starts to play a song at the radio station. The song is transmitted by radio waves to a listener with his ear right next to a radio that is 100 km away from the station. The song is sent to the disc jockey by sound waves from a speaker that is 3 meters away. Who hears the song first? What is the time lag between the two signals? Use 343 m/s for the speed of sound in air.

1.2 Reflection & Refraction

1) A swimmer is underwater and sees the Sun at an apparent angle of 45° above the horizontal surface of the water. What is the actual elevation angle of the Sun above the water's surface?

2) A red laser pointer has a wavelength of 670 nm in air. (a) What is the light's frequency? (b) What is the light's wavelength in a piece of glass with an index of 1.50? (c) How fast does the light travel in this glass?

3) A ray of light hits a flat block of plastic with an index of 1.45 of thickness 2 cm at an angle of incidence of 30°. Trace the light through the plastic and find the angle of incidence and refraction at the top and bottom surface.

4) When the light shown in Figure 1.2.1 leaves the glass block, it is shifted horizontally from its original path by distance *d*. Find the value of *d* if the index of refraction of the glass is 1.60.

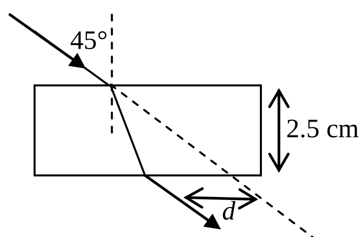

Fig. 1.2.1

5) Find the critical angle for 589-nm light in the following materials if they are surrounded by air: (a) diamond (n = 2.419), (b) fused quartz (n = 1.458), and (c) ice (n = 1.309).

6) A small light fixture at the bottom of a fountain is 50 centimeters below the surface. The light from the bulb forms a circle on the surface of the water. Find the diameter of the circle.

1.3 Image Formation

1) A glass cube with 4 cm sides is placed on top of a penny. When viewed from directly overhead, the penny appears to be inside the cube, 2.8 cm below its top surface. Find the refractive index of the glass.

2) The left side of a converging lens has a radius of curvature of +12 cm. The refractive index of the glass is 1.44. The focal length of the lens is 16.4 cm when used in air. (a) Find the radius of curvature of the right side of the lens. (b) What is the focal length of the lens if it is flipped so that the original left side is now the right side?

3) A converging lens has a focal length of 20 cm. For object distances of (a) 40 cm, (b) 30 cm, and (c) 20 cm, find the image distance, find the lateral magnification, state whether the image is real or virtual, and state whether the image is inverted or not inverted.

4) A 3-cm tall object is placed 20 cm from the left side of a diverging lens with a focal length of -15 cm. Find the location of the image, its height, and state whether it is real or virtual and inverted or not inverted.

1.4 Simple Optical Systems

1) A certain projector uses a single positive lens. An object that is 24 mm tall is to have its image projected onto a 1.8-meter tall screen so that the image fills the screen. The distance between the screen and the object is 3 meters. (a) Find the focal length of the lens to accomplish this task. (b) How far should the object be from the lens?

2) An image of an object is four times as big as the object when viewed through a magnifying glass when the lens is 30 cm from the image. Find the focal length of the lens.

3) A nearsighted person cannot see objects clearly beyond 32 cm. What type of lens and what power are necessary to correct her sight?

4) A lens with a focal length of +5 cm is used as a magnifying glass. (a) To obtain the maximum useful magnification, how far should the lens be from the object? (b) What is this magnification in (a)?

5) The refracting telescope at the Yerkes Observatory has an objective lens with one-meter diameter and a twenty-meter focal length. If an astronomer looks through the telescope using an eyepiece with a focal length of 2.5 cm, find the total magnification of the telescope. Is the image inverted or not inverted?

Part 2: Physical Optics

2.1 Interference

1) Two antennas separated by 300 m as shown in Figure 2.1.1 simultaneously broadcast radio waves at the same wavelength. The radio in a car traveling north as shown receives the interfered signal. (a) The car is at the position shown and is receiving the second maximum in the interference pattern. Find the wavelength of the waves. (b) How much farther must the car travel to receive the next minimum? (Do not use the small angle approximation since the 1000 m is not much greater than the 300 m of antenna separation.)

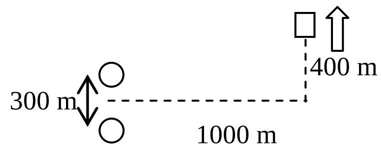

Fig. 2.1.1

2) A double slit pattern is formed on a wall that is 2 m from the slits with 589-nm light. The tenth interference minimum appears 7.26 mm from the central maximum. Find the spacing of the slits.

3) Two parallel slits are separated by 0.25 mm and illuminated with green light at a wavelength of 546.1 nm. The pattern is observed on a screen that is 120 cm from the slits. (a) Find the distance between the central maximum and the center of the first bright fringe on either side of the central maximum. (b) What is the distance between the centers of two consecutive dark fringes?

4) White light is sent through a grating with grooves that has 2000 grooves per cm. At what angle does 640-nm red light appear in first order?

5) The visible emission spectrum of hydrogen includes a red line at 656 nm and a violet line at 434 nm. Find the angular separation of these two lines in first order and second order if a grating with 450 grooves per mm is used to view the spectrum..

6) A 280-nm thick oil film is floating on water and is illuminated by white light near normal incidence. Find the color that is most strongly reflected and the color that is most strongly transmitted. Use a refractive index of 1.45 for the oil.

7) A soap bubble is floating in air. If the bubble wall (n=1.33) is 115 nm thick, what color is most strongly reflected at normal incidence?

8) A material with an index of 1.30 is used as an antireflective coating on a piece of glass with an index of 1.5. What is the minimum film thickness that will minimize reflection of 500-nnm light?

9) A Michelson interferometer is used with a He-Ne laser (wavelength of 632.8 nm). One of the mirrors is moved and 250 fringe reversals are counted. (This means 125 total fringe shifts.) How far is the mirror moved?

2.2 Diffraction

1) He-Ne laser light (632.8 nm wavelength) is sent through a 0.3-mm wide slit. How wide is the central diffraction peak on a screen that is 1 meter from the slit?

2) A screen is placed 50 cm from a single slit. Light at 690 nm is sent through the slit and viewed on the screen. The distance between the first and third minima is 3 mm. Find the width of the slit.

3) Sound at a frequency of 650 Hz from a distant source passes through a 1.1-m wide doorway. Find the number and approximate directions of the diffraction-maximum beams that are radiated into the room beyond.

4) Potassium iodide (KI) has sets of atomic planes separated by 3.53 Angstroms. In a certain x-ray spectrometer, the first order diffraction peak of this crystal occurs at an angle of 7.6°. What is the wavelength of the x-rays in this device?

5) X-ray diffraction is performed on a sample of NaCl crystal using 0.14-nm x-rays. The first order maximum is seen at 14.4°. What is the separation distance between the atomic planes of the crystal?

6) A helium-neon laser sends 632.8-nm light through a circular aperture with a diameter of 0.50 cm. Estimate the width of the beam 10 km from the laser.

7) Impressionist painters were known for painting closely spaced "dots" to form an image when viewed from afar. Suppose the dots in one painting are 2 mm in diameter. What is the closest you could get to the painting without resolving the individual dots? Use a free-space wavelength of 560 nm. Assume a pupil diameter of 4 mm and a refractive index of 1.33 inside the eyeball.

8) A hawk is circling in the sky 30 meters above the ground. It spots a mouse. What is the minimum distance between two of the mouse's whiskers if the hawk can resolve them? Assume the hawk's pupil is 12 mm wide and that its eye is most sensitive to 500-nm light.

2.3 Polarization

1) Linear-polarized light hits a single polarizer with its electric field parallel to the polarizer's transmission axis. Through what angle should the polarizer be rotated so that the intensity is reduced by a factor of (a) 3, (b) 5, and (c) 10?

2) The critical angle for TIR for sapphire surrounded by air is 34.4°. Calculate the polarization angle for light that is reflected off of sapphire.

3) For a transparent material surrounded by air, show that the critical angle for TIR and the polarization angle are related by the expression $\cot \theta_p = \sin \theta_c$.

Part 3: Quantum Physics

3.1 Thermal Radiation and Photons

1) The human eye is most sensitive to light with a free-space wavelength around 560 nm. What is the temperature of an object if it radiates most intensely at this wavelength?

2) The diameter of the Sun is approximately 1.392×10^{6} km. Its total output power is approximately 3.85×10^{26} W. (a) Assuming that the Sun is a black body at one temperature, find its surface temperature. (b) Find the wavelength of peak emission from the Sun's surface.

3) Find the energy in electron volts, the free-space wavelength, and the part of the spectrum for the following photons: (a) 620 THz, (b) 3.1 GHz, and (c) 46 MHz.

4) An FM radio transmitter delivers 150 kW at 99.7 MHz. How many photons per second are transmitted?

3.2 Photoelectric Effect

1) When green light from a mercury lamp (λ = 546.1 nm) hits a metal, a stopping potential of 0.376 V is required to reduce the photocurrent to zero. (a) Find the work function of the metal. (b) If yellow light with λ = 587.5 nm hit the same metal, what stopping potential would be measured?

2) The work functions of Li, Be, and Hg are 2.30 eV, 3.90 eV, and 4.50 eV, respectively. Light with a wavelength of 400 nm hits all three metals in an experiment. (a) Which of the metals will exhibit the photoelectric effect? (b) Find the maximum kinetic energy of a photoelectron for the metals that do exhibit the photoelectric effect.

3.3 Compton Scattering

1) X-rays with a wavelength of 120 pm are used in a Compton scattering experiment. (a) Find the wavelengths of the x-rays scattered at angles of 30°, 90°, 150°, and 180°. (b) Find the energy of the scattered electron in each case. (c) Which of these angles results in the electron having the highest kinetic energy? (d) Explain how you could answer (c) without first calculating the electron energies.

2) A photon having a wavelength of λ scatters off a free electron at *A* in Figure 3.3.2 producing a scattered photon with wavelength λ'. This photon scatters off another free electron at *B* producing a third photon with wavelength λ'' that moves off in a direction that is directly opposite the original photon's direction. Find the numerical value of $\Delta\lambda = \lambda'' - \lambda$.

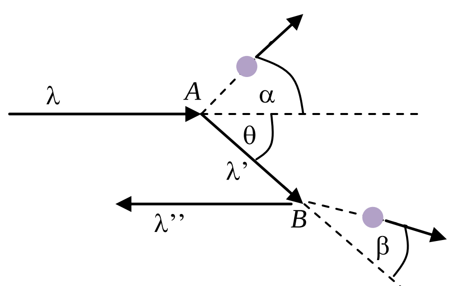

Fig. 3.3.2

3.4 Bohr Model of Hydrogen

1) What value of n_i is associated with the 94.96-nmn spectral line in the Lyman series of hydrogen? The Lyman series consists of transitions to the ground state of hydrogen.

2) The Balmer series for hydrogen consists of transitions to the first excited state from higher energy states. (a) Find the energy and wavelength of the longest wavelength photon in the series. (b) Find the energy and wavelength of the shortest wavelength photon in the series.

3) A hydrogen atom is in its first excited state. Find (a) the radius of its orbit, (b) the linear momentum of the electron, (c) the angular momentum of the electron, (d) the kinetic energy of the electron, (e) the potential energy of the electron, and (f) the total energy of the atomic system.

3.5 Theory of Quantum Mechanics

1) Find the deBroglie wavelength of a proton moving at 10^6 m/s.

2) (a) An electron has a kinetic energy of 3.0 eV. Find its matter wavelength. (b) Find the wavelength of a photon with an energy of 3.0 eV.

3) Neutrons travelling at 40 cm/s are directed through a pair of slits with a separation of 1 mm. A detector array is placed 10 m from the slits. (a) Find the wavelength of one of the neutrons. (b) How far off the central axis point is the first zero-intensity point on the array? (c) When a neutron reaches the array, can we say which slit the neutron passed through?

4) An electron and a bullet with a mass of 20 grams each have a speed of 500m/s accurate to within 0.01%. Within what limits could one determine the positions of the electron and bullet if simultaneous measurements of position and speed were made?

5) An electron is trapped inside a one-dimensional, infinite square well of width 0.1 nm. (a) Find the energies of the first four states. (b) Find the wavelengths of all of the photons that could be emitted if the electron starts in the $n = 4$ state and makes it way to the ground state.

6) A ruby laser emits 694.3-nm light. Assume that light of this wavelength is emitted by an electron inside a one-dimensional, infinite square well as it makes a transition from the first excited state to the ground state. Find the width of the well.

7) The nuclear potential energy that binds protons to neutrons inside a nucleus can be approximated by a square well. Imagine a proton confined in an infinitely high well of width 10 fm, a typical nucleus diameter. Calculate the wavelength and energy of the photon emitted if the proton makes a transition from the n=2 state to the n=1 state. In what part of the spectrum is this photon?

8) The ground-state wave function for a particle inside a one-dimensional square well of width L is $\psi(x) = A \sin(\pi x / L)$ where the well extends from x=0 to x=L.. Use the normalization condition to show that the amplitude A is given by $(2 / L)^{1/2}$.

3.6 Atomic Physics

1) How many sets of quantum numbers are possible for a hydrogen atom for which (a) n=1 and (b) n=3? Do this by listing all possible sets. Do your answers agree with the rule that there are $2n^2$ states for a shell with quantum number n?

2) The carbon dioxide laser is one of the most powerful lasers that has been developed. The energy difference between the two lasing levels is 0.117 eV. Find the frequency and wavelength of the emitted laser light. In what part of the spectrum is this radiation?

3) A ruby laser (λ = 694.3 nm) delivers 1 MW of average power in a 10-ns pulse. How many photons are in the pulse?

Part 4: Special Theory of Relativity

4.1 Length & Time

1) How fast does a clock move if it is measured to run at a rate that is one-half the rate of a clock that is stationary?

2) A muon formed in the Earth's atmosphere travels at 0.99*c* for a distance of 4.6 km as measured by a scientist before it decays into an electron, a neutrino, and a n antineutrino. (a) How long does the muon live in its reference frame? (b) What distance does the muon see the Earth travel during the muon's lifetime?

3) A spaceship with a proper length of 300 meters takes 0.75 μs to pass an Earth-based observer on the observer's clock. What is the speed of the ship measured by the observer?

4) You and your friend buy identical spaceships. You are sitting in your ship at the space dock when your friend zooms by in his ship. He tells you that his ship is 20 meters long and that your ship is 19 meters long. According to your measurements, (a) how long is your ship, (b) how long is your friend's ship, and (c) how fast is your friend flying?

4.2 Velocity

1) Two jets of particles are ejected from the center of a radio galaxy in opposite directions. Both jets move at 0.75*c* relative to the galaxy. Determine the speed of one jet relative to the other one.

2) A Klingon spacecraft moves away from Earth at 0.80*c*. The starship Enterprise pursues the Klingon vessel at 0.90*c* relative to the Earth. (a) With what speed is the Enterprise overtaking the Klingon ship as seen observers on Earth? (b) With what speed is the Enterprise overtaking the Klingon ship as seen the Enterprise crew?

4.3 Momentum & Energy

1) A proton moves at *c*/2 in an accelerator. How much energy is required to increase its speed to (a) 0.75*c* and (b) 0.995*c*?

2) Find the momentum in units of MeV/*c* of an electron if its total energy is twice its rest energy.

3) A proton moves at 95% the speed of light in vacuum. Find its (a) rest energy, (b) total energy, and (c) kinetic energy.

4) In an old color tv set that used a tube, electrons were accelerated from rest through a voltage difference of 25 kV. (a) How fast were the electrons moving when they struck the screen? (b) What was their kinetic energy expressed in Joules?

5) The power output of the Sun is 3.85×10^{26} W. Use this figure to estimate how much mass is converted to energy each second in the Sun.

Part 5: Nuclear Physics

5.1 The Nucleus

1) Find the radius of (a) a He-4 nucleus and (b) a U-238 nucleus.

2) A star ending its life with a mass that is twice that of our sun is expected to collapse and form a neutron star. Such a star can be modeled as a giant nucleus. What would be the approximate radius of such a star? (Our sun's mass is 1.99×10^{30} kg and that of a neutron is around 1.67×10^{-27} kg.)

3) Calculate the binding energy per nucleon for (a) H-2, (b) He-4, (c) Fe-56, and (d) U-238.

4) Nuclei with the same *mass* numbers are called *isobars*. Consider the three isobars of La-139, Pr-139, and Cs-139. (a) Which isobar has the highest neutron-to-proton ratio? (b) Which has the highest binding energy per nucleon?

5) A pair of nuclei for which $Z_1 = N_2$ and $Z_2 = N_1$ are called *mirror isobars*. Calculate the difference in binding energy for the two mirror isobars of O-15 and N-15. The electric repulsion of 8 protons rather than 7 protons accounts for the difference.

5.2 Radioactivity

1) A radioactive sample contains 10^{15} atoms and has an activity of 6×10^{11} Bq. What is its half-life?

2) A radioactive sample is prepared with an initial activity of 10 mCi. Four hours later, its activity is 8 mCi. (a) Find the decay constant and half-life of the isotope. (b) How many atoms were in the original sample? (c) What is the activity of this sample 30 hours after preparation?

3) Enter the correct isotope symbol in each open square in Figure 5.2.3 which shows the natural decay sequence of U-235 to the stable lead isotope Pb-207.

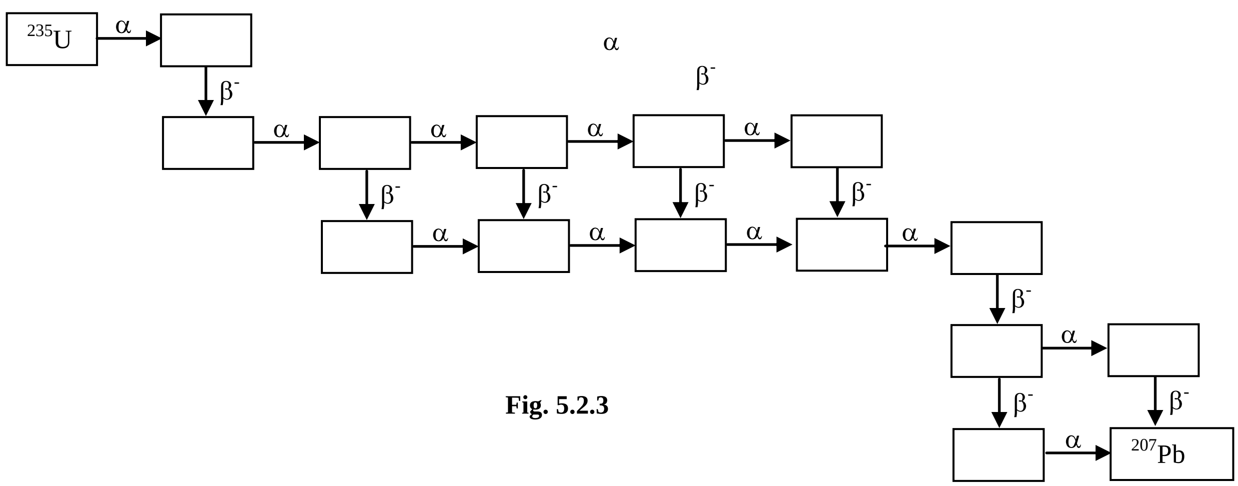

Fig. 5.2.3

4) Radon-222 has a half-life of 3.82 days and is one of the decay products in the decay sequence of Uranium-238. The radon seeps out of the ground to mix with air, typically making open air radioactive with an activity of 0.3 pCi/liter. In homes, radon can be trapped indoors giving rise to higher levels. Levels above 4 pCi/liter or so are considered high enough that action should be taken to reduce the trapped radon. (a) Convert the 4 pCi/liter to units of Bq/m^3. (b) Find the number of Rn-222 atoms in one cubic meter of air with this level of activity. (c) What fraction of the mass of the air is this amount of radon?

5) The radioactivity of milk in Poland rose to 2000 Bq/liter after the Chernobyl accident in 1986. The increase was due to iodine-131 present in the grass eaten by dairy cattle. This iodine isotope has a half-life of 8.04 days. (a) For comparison, calculate a normal activity of milk due to the radioactive potassium-40 isotope. Assume that 1 liter of milk contains 2 grams of potassium, of which 0.0117% is K-40. The half-life of K-40 is 1.28 billion years. (b) After how many days did the activity due to the iodine fall below that due to the potassium?

6) A storage room has been accidentally contaminated by a radioactive spill of five kilograms of strontium-90. The half-life of the isotope is 29.1 years and its atomic mass is 89.9077 u. The safe level of activity is 10 decays per minute. How long will the room be unsafe?

7) An x-ray tech takes an average of 8 x-rays per day and receives a dose of 5 rems per year. (a) Estimate the dose in rem for each x-ray. (b) How does this tech's annual dose compare to a typical annual dose?

8) When gamma rays enter a material, the intensity of the gamma rays decreases with depth according to $I(x) = I_o e^{-\mu x}$ where I_o is the intensity at the surface of the material (x=0) and μ is the absorption coefficient. For 0.40-MeV gamma rays traveling in lead, the coefficient is 1.59 cm^{-1}. (a) Find the "half-thickness" of lead, i.e. the thickness that will reduce the intensity by one-half. (b) What thickness is needed to reduce the intensity by a factor of 10,000?

5.3 Nuclear Power

1) One possible fission reaction in a nuclear power plant is one neutron combining with one U-235 nucleus to produce one Ba-141 nucleus, one Kr-92 nucleus, and three neutrons. (a) Find the energy released in this fission. The masses of Ba-141 and Kr-92 are 140.9144 u and 91.9262 u, respectively. (b) What fraction of the initial mass is converted to energy?

PHYSICS III: ANSWERS TO PRACTICE PROBLEMS

1-1.

1. (a) 3 m, radio (b) 625 nm, visible (red) (c) 15 cm, microwave (d) 1.5 pm, x-ray or gamma (can't tell which without more information)
2. (a) 474.1 THZ (b) 3183 W/m^2 (c) 1548 V/m (d) 5.2 μT
3. The listener hears the song first. It takes about 0.33 ms for the song to travel to the listener and about 8.75 ms to travel to the disc jockey. That is a difference of about 8.42 ms.

1-2.

1. 19.5°
2. (a) 447.76 THz (b) 446.7 nm (c) $c/1.50 = 2\times10^8$ m/s
3. Top: incident angle = 30°, refracted angle = 20.2° Bottom: incident angle = 20.2°, refracted angle = 30°
4. 1.27 cm
5. (a) 24.4° (b) 43.3° (c) 49.8°
6. 114 cm

1-3.

1. 1.43
2. (a) -18 cm (b) 16.4 cm (doesn't change)
3. (a) 40 cm, later mag = -1, real, inverted (b) 60 cm, later mag = -3, real, inverted (c) no image is formed
4. The image is on the left side of the lens, 8.57 cm from the lens. It is 1.29 cm tall, virtual, and not inverted.

1-4.

1. (a) 39.5 mm (b) 40 mm
2. 7.89 cm
3. negative lens with a power of -3.125 diopters
4. (a) 4.17 cm (b) 6x
5. -800x and image is inverted

2-1.

1. (a) 55.7 m (b) 124 m
2. 1.54 mm
3. (a) 2.62 mm (b) 2.62 mm
4. 7.35º
5. 5.9º and 13.2 º
6. green is most reflected and violet is most transmitted
7. orange light near 612 nm is the only visible light that is strongly reflected
8. 96.2 nm
9. 39.6 μm

2-2.

1. 4.22 mm
2. 0.23 mm
3. 3 maxima, one straight into the room at 0° and two about 46° on either side from the straight beam
4. 0.93 Angstroms
5. 2.81 Angstroms
6. 3.09 m
7. 15.57 m
8. 1.52 mm

2-3.

1. (a) 54.7° (b) 63.4° (c) 71.6°
2. 60.5°

3-1.

1. 5180 K
2. (a) 5780 K (b) 501 nm
3. (a) 2.57 eV, 484 nm (visible) (b) 1.28×10^{-7} eV, 9.68 cm (microwaves) (c) 1.91×10^{-7} eV, 6.52 m (radio)
4. 2.27×10^{30} photons /s

3-2.

1. (a) 1.90 eV (b) 0.216 V
2. (a) only Li (The other metals have work functions that are greater than the 400-nm photon energy.) (b) 0.808 eV

3-3.

1. (a) 120.326 pm, 122.430 pm, 124.534 pm, 124.860 pm (b) 28 eV, 206 eV, 377 eV, 403 eV (c) 180° (d) When the scattering angle is 180°, the photon completely backscatters. By conservation of momentum, this must result in the electron receiving the largest possible momentum in the collision
2. 4.86 pm

3-4.

1. 5
2. (a) 1.89 eV, 656 nm (b) 3.40 eV, 365 nm
3. (a) 2.12 Å (b) 9.95×10^{-25} kg-m/s (c) 2.11×10^{-34} J-s (d) 3.40 eV (e) -6.80 eV (f) -3.40 eV

3-5.

1. 0.004 Å
2. (a) 0.709 nm (b) 414 nm
3. (a) 993 nm (b) 4.96 mm (c) no
4. Within 1.16 mm for the electron, within 5.3×10^{-32} m for the bullet
5. (a) 37.7 eV, 151 eV, 339 eV, 603 eV (b) 2.20 nm, 2.75 nm, 4.12 nm, 4.71 nm, 6.60 nm, 11.0 nm
6. 0.793 nm
7. 6.16 MeV, 202 fm, gamma ray
8. Integrate ψ^2 from x=0 to x=L.

3-6.

1. (a) 2 (b) 18
2. 28.2 THz, 10.6 μm, infrared
3. 3.49×10^{16}

4-1.

1. 0.866c
2. (a) 2.18 μs (b) 649 m
3. 0.80c
4. (a) 20 m (b) 19 m (c) 0.312c

4-2.

1. 0.96c
2. (a) 0.1c (b) 0.357c

4-3.

1. (a) 335.6 MeV (b) 8.31 GeV
2. 1630 MeV/c
3. (a) 938 MeV (b) 3.00 GeV (c) 2.07 GeV
4. (a) 0.302c (b) 25 keV = 4×10^{-15} J
5. 4.3 billion kg each second

5-1.

1. (a) 1.90 fm (b) 7.44 fm
2. 16 km
3. (a) 1.11 MeV (b) 7.07 MeV (c) 8.79 MeV (d) 7.57 MeV
4. (a) Cs-139 (b) La-139
5. Greater for N-15 by 3.54 MeV

5-2.

1. 1.16 ks = 19.3 min
2. (a) 1.55×10^{-5} /s , 12.4 h (b) 2.39×10^{13} atoms (c) 1.88 mCi
3. You fill it out!
4. (a) 148 Bq/m^3 (b) 70.5 million/m^3 (c) 2.17×10^{-17}
5. (a) 61.8 Bq/liter (b) 40.3 days
6. 1660 years

7. (a) 2.5 mrem per image (b) A typical annual dose is 200 mrem. This tech receives 5000 mrem, 25 times a typical dose.
8. (a) 4.4 mm (b) 57.9 mm

<u>5-3.</u>

1. (a) 173 MeV (b) 0.079%