Problems:

Section 40.1 Blackbody Radiation and Planck's Hypothesis
1. The temperature of an electric heating element is 150°C. At what wavelength does the radiation emitted from the heating element reach its peak?
6. (i) Calculate the energy, in electron volts, of a photon whose frequency is (a) 620 THz, (b) 3.10 GHz, and (c) 46.0 MHz. **(ii)** Determine the corresponding wavelengths for the photons listed in part (i) and **(iii)** state the classification of each on the electromagnetic spectrum.
8. An FM radio transmitter has a power output of 150 kW and operates at a frequency of 99.7 MHz. How many photons per second does the transmitter emit?
10. The radius of our Sun is 6.96×10^8 m, and its total power output is 3.85×10^{26} W. (a) Assuming the Sun's surface emits as a black body, calculate its surface temperature. (b) Using the result of part (a), find λ_{max} for the Sun.
11. A black body at 7 500 K consists of an opening of diameter 0.050 0 mm, looking into an oven. Find the number of photons per second escaping the opening and having wavelengths between 500 nm and 501 nm.
Section 40.2 The Photoelectric Effect
17. Molybdenum has a work function of 4.20 eV. (a) Find the cutoff wavelength and cutoff frequency for the photoelectric effect. (b) What is the stopping potential if the incident light has a wavelength of 180 nm?
18. The work function for zinc is 4.31 eV. (a) Find the cutoff wavelength for zinc. (b) What is the lowest frequency of light incident on zinc that releases photoelectrons from its surface? (c) If photons of energy 5.50 eV are incident on zinc, what is the maximum kinetic energy of the ejected photoelectrons?
19. Two light sources are used in a photoelectric experiment to determine the work function for a particular metal surface. When green light from a mercury lamp (l 5 546.1 nm) is used, a stopping potential of 0.376 V reduces the photocurrent to zero. (a) Based on this measurement, what is the work function for this metal? (b) What stopping potential would be observed when using the yellow light from a helium discharge tube (l 5 587.5 nm)?
21. Electrons are ejected from a metallic surface with speeds of up to 4.60×10^5 m/s when light with a wavelength of 625 nm is used. (a) What is the work function

of the surface? (b) What is the cutoff frequency for this surface?
Section 40.5 The Wave Properties of Particles
39. (a) Calculate the momentum of a photon whose wavelength is 4.00×10^{-7} m. (b) Find the speed of an electron having the same momentum as the photon in part (a).
40. (a) An electron has a kinetic energy of 3.00 eV. Find its wavelength. (b) **What If?** A photon has energy 3.00 eV. Find its wavelength.
42. Calculate the de Broglie wavelength for a proton moving with a speed of 1.00×10^6 m/s.
Section 42.1 Atomic Spectra of Gases
1. The wavelengths of the Lyman series for hydrogen are given by $$\frac{1}{\lambda} = R_H\left(1 - \frac{1}{n^2}\right) \quad n = 2, 3, 4, \ldots$$ (a) Calculate the wavelengths of the first three lines in this series. (b) Identify the region of the electromagnetic spectrum in which these lines appear.
2. The wavelengths of the Paschen series for hydrogen are given by $$\frac{1}{\lambda} = R_H\left(\frac{1}{3^2} - \frac{1}{n^2}\right) \quad n = 4, 5, 6, \ldots$$ (a) Calculate the wavelengths of the first three lines in this series. (b) Identify the region of the electromagnetic spectrum in which these lines appear.
5. (a) What value of n_i is associated with the 94.96-nm spectral line in the Lyman series of hydrogen? (b) **What If?** Could this wavelength be associated with the Paschen series? (c) Could this wavelength be associated with the Balmer series?
Section 42.2 Early Models of the Atom
7. Review. In the Rutherford scattering experiment, 4.00-MeV alpha particles scatter off gold nuclei (containing 79 protons and 118 neutrons). Assume a particular alpha particle moves directly toward the gold nucleus and scatters backward at 180°, and that the gold nucleus remains fixed throughout the entire process. Determine (a) the distance of closest approach of the alpha particle to the gold nucleus and (b) the maximum force exerted on the alpha particle.
Section 42.3 Bohr's Model of the Hydrogen Atom
Note: In this section, unless otherwise indicated, assume the hydrogen atom is treated with the Bohr model.

9. How much energy is required to ionize hydrogen (a) when it is in the ground state and (b) when it is in the state for which $n = 3$?
10. What is the energy of a photon that, when absorbed by a hydrogen atom, could cause an electronic transition from (a) the $n = 2$ state to the $n = 5$ state and (b) the $n = 4$ state to the $n = 6$ state?
11. A photon is emitted when a hydrogen atom undergoes a transition from the *n* 5 5 state to the *n* 5 3 state. Calculate (a) the energy (in electron volts), (b) the wavelength, and (c) the frequency of the emitted photon.
17. A hydrogen atom is in its second excited state, corresponding to *n* 5 3. Find (a) the radius of the electron's Bohr orbit and (b) the de Broglie wavelength of the electron in this orbit.
Section 42.8 More on Atomic Spectra: Visible and X-Ray
49. What minimum accelerating voltage would be required to produce an x-ray with a wavelength of 70.0 pm?
50. A tungsten target is struck by electrons that have been accelerated from rest through a 40.0-keV potential difference. Find the shortest wavelength of the radiation emitted.
54. The K series of the discrete spectrum of tungsten contains wavelengths of 0.018 5 nm, 0.020 9 nm, and 0.021 5 nm. The K-shell ionization energy is 69.5 keV. Determine the ionization energies of the L, M, and N shells.
Section 42.9 Spontaneous and Stimulated Transitions **Section 42.10 Lasers**
59. The carbon dioxide laser is one of the most powerful developed. The energy difference between the two laser levels is 0.117 eV. Determine (a) the frequency and (b) the wavelength of the radiation emitted by this laser. (c) In what portion of the electromagnetic spectrum is this radiation?
61. A ruby laser delivers a 10.0-ns pulse of 1.00-MW average power. If the photons have a wavelength of 694.3 nm, how many are contained in the pulse?
Section 44.1 Some Properties of Nuclei
1. Find the nuclear radii of (a) ${}^{2}_{1}\mathrm{H}$, (b) ${}^{60}_{27}\mathrm{Co}$, (c) ${}^{197}_{79}\mathrm{Au}$, and (d) ${}^{239}_{94}\mathrm{Pu}$.

2. (a) Determine the mass number of a nucleus whose radius is approximately equal to two-thirds the radius of ${}^{230}_{88}Ra$ (b) Identify the element. (c) Are any other answers possible? Explain.
4. (a) What is the order of magnitude of the number of protons in your body? (b) Of the number of neutrons? (c) Of the number of electrons?
5. Consider the ${}^{65}_{29}Cu$ nucleus. Find approximate values for its (a) radius, (b) volume, and (c) density.
6. Using 2.30×10^{17} kg/m^3 as the density of nuclear matter, find the radius of a sphere of such matter that would have a mass equal to that of a baseball, 0.145 kg.
Section 44.2 Nuclear Binding Energy
15. Calculate the binding energy per nucleon for (a) ^{2}H, (b) ^{4}He, (c) ^{56}Fe, and (d) ^{238}U.
Section 44.4 Radioactivity
25. What time interval is required for the activity of a sample of the radioactive isotope ${}^{72}_{33}As$ to decrease by 90.0% from its original value? The half-life of ${}^{72}_{33}As$ is 26 h.
27. A sample of radioactive material contains 1.00×10^{15} atoms and has an activity of 6.00×10^{11} Bq. What is its half-life?
29. The radioactive isotope ${}^{198}Au$ has a half-life of 64.8 h. A sample containing this isotope has an initial activity (t = 0) of 40.0 mCi. Calculate the number of nuclei that decay in the time interval between t_1 = 10.0 h and t_2 = 12.0 h.
30. A radioactive nucleus has half-life T1/2. A sample containing these nuclei has initial activity R_0 at t = 0. Calculate the number of nuclei that decay during the interval between the later times t_1 and t_2.
31. The half-life of ${}^{131}I$ is 8.04 days. (a) Calculate the decay constant for this nuclide. (b) Find the number of ${}^{131}I$ nuclei necessary to produce a sample with an activity of 6.40 mCi. (c) A sample of ${}^{131}I$ with this initial activity decays for 40.2 d. What is the activity at the end of that period?
32. Tritium has a half-life of 12.33 years. What fraction of the nuclei in a tritium sample will remain (a) after 5.00 yr? (b) After 10.0 yr? (c) After 123.3 yr? (d)

According to Equation 44.6, an infinite amount of time is required for the entire sample to decay. Discuss whether that is realistic.

33. Consider a radioactive sample. Determine the ratio of the number of nuclei decaying during the first half of its half-life to the number of nuclei decaying during the second half of its half-life.

Section 44.5 The Decay Processes

35. Determine which decays can occur spontaneously.

(a) ${}^{40}_{20}\mathrm{Ca} \rightarrow e^{+} + {}^{40}_{19}\mathrm{K}$

(b) ${}^{98}_{44}\mathrm{Ru} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{94}_{42}\mathrm{Mo}$

(c) ${}^{144}_{60}\mathrm{Nd} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{140}_{58}\mathrm{Ce}$

38. Identify the unknown nuclide or particle (X).

(a) $\mathrm{X} \rightarrow {}^{65}_{28}\mathrm{Ni} + \gamma$

(b) ${}^{215}_{84}\mathrm{Po} \rightarrow \mathrm{X} + \alpha$

(c) $\mathrm{X} \rightarrow {}^{55}_{26}\mathrm{Fe} + e^{+} + v$

(d) ${}^{109}_{48}\mathrm{Cd} + \mathrm{X} \rightarrow {}^{109}_{47}\mathrm{Ag} + v$

(e) ${}^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \rightarrow \mathrm{X} + {}^{17}_{8}\mathrm{O}$

Section 44.6 Natural Radioactivity

44. The most common isotope of radon is ^{222}Rn, which has half-life 3.82 days. (a) What fraction of the nuclei that were on Earth one week ago are now undecayed? (b) What fraction of those that existed one year ago? (c) In view of these results, explain why radon remains a problem, contributing significantly to our background radiation exposure.

Section 44.7 Nuclear Reactions

47. A beam of 6.61-MeV protons is incident on a target of ${}^{27}_{13}\mathrm{Al}$. Those that collide produce the reaction

$$p + {}^{27}_{13}\mathrm{Al} \rightarrow {}^{27}_{14}\mathrm{Si} + n$$

Ignoring any recoil of the product nucleus, determine the kinetic energy of the emerging neutrons.

49. Identify the unknown nuclides and particles X and X′ in the nuclear reactions (a)

(a) $\mathrm{X} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{24}_{12}\mathrm{Mg} + {}^{1}_{0}n$

(b) ${}^{235}_{92}\mathrm{U} + {}^{1}_{0}n \rightarrow {}^{90}_{38}\mathrm{Sr} + \mathrm{X} + 2\,{}^{1}_{0}n$

(c) $2{}_{1}^{1}\mathrm{H} \rightarrow {}_{1}^{2}\mathrm{H} + \mathrm{X} + \mathrm{X}'$
Section 45.2 Nuclear Fission
1. If the average energy released in a fission event is 208 MeV, find the total number of fission events required to operate a 100-W lightbulb for 1.0 h.
2. Burning one metric ton (1 000 kg) of coal can yield an energy of 3.30 3 1010 J. Fission of one nucleus of uranium-235 yields an average of approximately 200 MeV. What mass of uranium produces the same energy in fission as burning one metric ton of coal?
4. A typical nuclear fission power plant produces approximately 1.00 GW of electrical power. Assume the plant has an overall efficiency of 40.0% and each fission reaction produces 200 MeV of energy. Calculate the mass of 235U consumed each day.
7. Find the energy released in the fission reaction $${}_{0}^{1}\mathrm{n} + {}_{92}^{235}\mathrm{U} \rightarrow {}_{38}^{88}\mathrm{Sr} + {}_{54}^{136}\mathrm{Xe} + 12({}_{0}^{1}\mathrm{n})$$
8. A 2.00-MeV neutron is emitted in a fission reactor. If it loses half its kinetic energy in each collision with a moderator atom, how many collisions does it undergo as it becomes a thermal neutron, with energy 0.039 eV?
Section 45.4 Nuclear Fusion
22. An all-electric home uses 2 000 kWh of electric energy per month. Assuming all energy released from fusion could be captured, how many fusion events described by the reaction $${}_{1}^{2}\mathrm{H} + {}_{1}^{3}\mathrm{H} \rightarrow {}_{2}^{4}\mathrm{He} + {}_{0}^{1}\mathrm{n}$$ would be required to keep this home running for one year?
23. Find the energy released in the fusion reaction $${}_{1}^{1}\mathrm{H} + {}_{1}^{2}\mathrm{H} \rightarrow {}_{2}^{3}\mathrm{He} + \gamma$$
25. (a) Consider a fusion generator built to create 3.00 GW of power. Determine the rate of fuel burning in grams per hour if the D–T reaction is used. (b) Do the same for the D–D reaction, assuming the reaction products are split evenly between (n, 3He) and (p, 3H).