7. (I) An HCl molecule vibrates with a natural frequency of 8.1×10^{13} Hz. What is the difference in energy (in joules and electron volts) between possible values of the oscillation energy?

8. (II) The steps of a flight of stairs are 20.0 cm high (vertically). If a 68.0-kg person stands with both feet on the same step, what is the gravitational potential energy of this person, relative to the ground, on (*a*) the first step, (*b*) the second step, (*c*) the third step, (*d*) the n^{th} step? (*e*) What is the change in energy as the person descends from step 6 to step 2?

9. (II) Estimate the peak wavelength of light issuing from the pupil of the human eye (which approximates a blackbody) assuming normal body temperature.

27–3 and 27–4 Photons and the Photoelectric Effect

10. (I) What is the energy of photons (joules) emitted by an 88.5-MHz FM radio station?

11. (I) What is the energy range (in joules and eV) of photons in the visible spectrum, of wavelength 400 nm to 750 nm?

12. (I) A typical gamma ray emitted from a nucleus during radioactive decay may have an energy of 300 keV. What is its wavelength? Would we expect significant diffraction of this type of light when it passes through an everyday opening, like a door?

13. (I) About 0.1 eV is required to break a "hydrogen bond" in a protein molecule. Calculate the minimum frequency and maximum wavelength of a photon that can accomplish this.

14. (I) Calculate the momentum of a photon of yellow light of wavelength 6.00×10^{-7} m.

15. (I) What is the momentum of a $\lambda = 0.010$ nm X-ray photon?

16. (II) The human eye can respond to as little as 10^{-18} J of light energy. For a wavelength at the peak of visual sensitivity, 550 nm, how many photons lead to an observable flash?

17. (II) What minimum frequency of light is needed to eject electrons from a metal whose work function is 4.3×10^{-19} J?

18. (II) What is the longest wavelength of light that will emit electrons from a metal whose work function is 3.10 eV?

19. (II) The work functions for sodium, cesium, copper, and iron are 2.3, 2.1, 4.7, and 4.5 eV, respectively. Which of these metals will not emit electrons when visible light shines on it?

20. (II) In a photoelectric-effect experiment it is observed that no current flows unless the wavelength is less than 570 nm. (*a*) What is the work function of this material? (*b*) What is the stopping voltage required if light of wavelength 400 nm is used?

21. (II) What is the maximum kinetic energy of electrons ejected from barium $(W_0 = 2.48\text{ eV})$ when illuminated by white light, $\lambda = 400$ to 750 nm?

22. (II) Barium has a work function of 2.48 eV. What is the maximum kinetic energy of electrons if the metal is illuminated by UV light of wavelength 365 nm? What is their speed?

23. (II) When UV light of wavelength 285 nm falls on a metal surface, the maximum kinetic energy of emitted electrons is 1.40 eV. What is the work function of the metal?

24. (II) The threshold wavelength for emission of electrons from a given surface is 350 nm. What will be the maximum kinetic energy of ejected electrons when the wavelength is changed to (*a*) 280 nm, (*b*) 360 nm?

25. (II) A certain type of film is sensitive only to light whose wavelength is less than 660 nm. What is the energy (eV and kcal/mol) needed for the chemical reaction to occur which causes the film to change?

26. (II) When 230-nm light falls on a metal, the current through a photoelectric circuit (Fig. 27–6) is brought to zero at a stopping voltage of 1.64 V. What is the work function of the metal?

27. (II) In a photoelectric experiment using a clean sodium surface, the maximum energy of the emitted photons was measured for a number of different incident frequencies, with the following results.

Frequency (10^{14} Hz)	Energy (eV)
11.8	2.60
10.6	2.11
9.9	1.81
9.1	1.47
8.2	1.10
6.9	0.57

Plot the graph of these results and find: (*a*) Planck's constant; (*b*) the cutoff frequency of sodium; (*c*) the work function.

28. (II). Show that the energy E (in electron volts) of a photon whose wavelength is λ (nm) is given by

$$E = \frac{1.240 \times 10^3\text{ eV}\cdot\text{nm}}{\lambda\text{ (nm)}}.$$

* 27–4 Compton Effect

* 29. (II) The quantity h/m_0c, which has the dimensions of length, is called the *Compton wavelength*. Determine the Compton wavelength for (*a*) an electron, (*b*) a proton. (*c*) Show that if a photon has wavelength equal to the Compton wavelength of a particle, the photon's energy is equal to the rest energy of the particle.

* 30. (II) X-rays of wavelength $\lambda = 0.120$ nm are scattered from carbon. What is the Compton wavelength shift for photons detected at angles (relative to the incident beam) of (*a*) 45°, (*b*) 90°, (*c*) 180°?

* 31. (III) In the Compton effect, a 0.100-nm photon strikes a free electron in a head-on collision and knocks it into the forward direction. The rebounding photon recoils directly backward. Use conservation of (relativistic) energy and momentum to determine (*a*) the kinetic energy of the electron, and (*b*) the wavelength of the recoiling photon. (*Note*: use Eq. 27–6, but not Eq. 27–7.)

27–6 Pair Production

32. (I) How much total kinetic energy will an electron–positron pair have if produced by a 3.84-MeV photon?

33. (II) What is the longest wavelength photon that could produce a proton–antiproton pair? (Each has a mass of 1.67×10^{-27} kg.)

34. (II) What is the minimum photon energy needed to produce a $\mu^+ - \mu^-$ pair? The mass of each μ (muon) is 207 times the mass of the electron. What is the wavelength of such a photon?

35. (II) An electron and a positron, each moving at 1.0×10^5 m/s, collide head on, disappear, and produce two photons, each with the same energy and momentum moving in opposite directions. What is the energy and momentum of each photon?

36. (II) A gamma-ray photon produces an electron–positron pair, each with a kinetic energy of 245 keV. What was the energy and wavelength of the photon?