10 – Quantum Mechanics (Ch. 38)

$c = 3 \cdot 10^8$ m/s; $h = 6.63 \cdot 10^{-14}$ J·s; 1 eV = $1.60 \cdot 10^{-19}$ J

42) The Sun is approximately an ideal blackbody radiator with a surface temperature of 5800 K. (a) Find the wavelength at which its spectral radiancy is maximum and (b) identify the type of electromagnetic wave corresponding to that wavelength. (See Fig. 33-1.) (c) The universe is approximately an ideal blackbody radiator with radiation emitted when atoms first formed. Today the spectral radiancy of that radiation peaks at a wavelength of 1.06 mm (in the microwave region). What is the corresponding temperature of the universe?

42. (a) Using Wien's law, $\lambda_{\max} T = 2898\ \mu\text{m}\cdot\text{K}$, we obtain

$$\lambda_{\max} = \frac{2898\ \mu\text{m}\cdot\text{K}}{T} = \frac{2898\ \mu\text{m}\cdot\text{K}}{5800\ \text{K}} = 0.50\ \mu\text{m} = 500\ \text{nm}\ .$$

(b) The electromagnetic wave is in the visible spectrum.

(c) If $\lambda_{\max} = 1.06\ \text{mm} = 1060\ \mu\text{m}$, then $T = \dfrac{2898\ \mu\text{m}\cdot\text{K}}{\lambda_{\max}} = \dfrac{2898\ \mu\text{m}\cdot\text{K}}{1060\ \mu\text{m}} = 2.73\ \text{K}$.

43) Just after detonation, the fireball in a nuclear blast is approximately an ideal blackbody radiator with a surface temperature of about $1.0 \cdot 10^7$ K. (a) Find the wavelength at which the thermal radiation is maximum and (b) identify the type of electromagnetic wave corresponding to that wavelength. (See Fig. 33-1.) This radiation is almost immediately absorbed by the surrounding air molecules, which produces another ideal blackbody radiator with a surface temperature of about $1.0 \cdot 10^5$ K. (c) Find the wavelength at which the thermal radiation is maximum and (d) identify the type of electromagnetic wave corresponding to that wavelength.

43. (a) Using Wien's law, the wavelength that corresponds to thermal radiation maximum is

$$\lambda_{\max} = \frac{2898\ \mu\text{m}\cdot\text{K}}{T} = \frac{2898\ \mu\text{m}\cdot\text{K}}{1.0\times 10^7\ \text{K}} = 2.9\times 10^{-4}\ \mu\text{m} = 2.9\times 10^{-10}\ \text{m}\ .$$

(b) The wave is in the x-ray region of the electromagnetic spectrum.

(c) Using Wien's law, the wavelength that corresponds to thermal radiation maximum is

$$\lambda_{\max} = \frac{2898\ \mu\text{m}\cdot\text{K}}{T} = \frac{2898\ \mu\text{m}\cdot\text{K}}{1.0\times 10^5\ \text{K}} = 2.9\times 10^{-2}\ \mu\text{m} = 2.9\times 10^{-8}\ \text{m}$$

(d) The wave is in the ultraviolet region of the electromagnetic spectrum.

15) Light strikes a sodium surface, causing photoelectric emission. The stopping potential for the ejected electrons is 5.0 V, and the work function of sodium is 2.2 eV. What is the wavelength of the incident light?

15. **THINK** The energy of an incident photon is $E = hf$, where h is the Planck constant, and f is the frequency of the electromagnetic radiation.

EXPRESS The kinetic energy of the most energetic electron emitted is

$$K_m = E - \Phi = (hc/\lambda) - \Phi,$$

where Φ is the work function for sodium, and $f = c/\lambda$, where λ is the wavelength of the photon.

The stopping potential V_{stop} is related to the maximum kinetic energy by $eV_{stop} = K_m$, so

$$eV_{stop} = (hc/\lambda) - \Phi$$

and

$$\lambda = \frac{hc}{eV_{stop} + \Phi} = \frac{1240\,\text{eV}\cdot\text{nm}}{5.0\,\text{eV} + 2.2\,\text{eV}} = 170\,\text{nm}.$$

Here $eV_{stop} = 5.0$ eV and $hc = 1240$ eV·nm are used.

LEARN The cutoff frequency for this problem is

$$f_0 = \frac{\Phi}{h} = \frac{(2.2\text{ eV})(1.6\times10^{-19}\text{ J/eV})}{6.626\times10^{-34}\,\text{J}\cdot\text{s}} = 5.3\times10^{14}\text{ Hz}.$$

61) The function $\psi(x)=Ae^{ikx}$ can describe a free particle, for which the potential energy is $U(x)=0$ in Schrödinger's equation. Assume now that $U(x) = U_0$ = a constant in that equation. Show that $\psi(x)$ is a solution of Schrödinger's equation

$$\frac{d^2\psi}{dx^2} + \frac{8\pi^2 m}{h^2}[E - U(x)]\psi = 0$$

for a specific value of the angular wave number k of the particle.