P11.33 (a) The major axis of the orbit is $2a = 50.5\text{ AU}$ so $a = 25.25\text{ AU}$

Further, in Figure 11.5, $a + c = 50\text{ AU}$ so $c = 24.75\text{ AU}$

Then $e = \frac{c}{a} = \frac{24.75}{25.25} = \boxed{0.980}$

(b) In $T^2 = K_s a^3$ for objects in solar orbit, the Earth gives us

$$(1\text{ yr})^2 = K_s(1\text{ AU})^3 \qquad K_s = \frac{(1\text{ yr})^2}{(1\text{ AU})^3}$$

Then $$T^2 = \frac{(1\text{ yr})^2}{(1\text{ AU})^3}(25.25\text{ AU})^3 \qquad T = \boxed{127\text{ yr}}$$

(c) $$U = -\frac{GMm}{r} = -\frac{(6.67\times10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2)(1.991\times10^{30}\text{ kg})(1.2\times10^{10}\text{ kg})}{50(1.496\times10^{11}\text{ m})} = \boxed{-2.13\times10^{17}\text{ J}}$$

Section 11.5 Atomic Spectra and the Bohr Theory of Hydrogen

P11.34 (a) The energy of the photon is found as $$E = E_i - E_f = \frac{-13.606\text{ eV}}{n_i^2} - \frac{(-13.606\text{ eV})}{n_f^2}$$

$$E = 13.606\text{ eV}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Thus, for $n = 3$ to $n = 2$ transition $$E = 13.606\text{ eV}\left(\frac{1}{4} - \frac{1}{9}\right) = \boxed{1.89\text{ eV}}$$

(b) $E = \frac{hc}{\lambda}$ and $$\lambda = \frac{6.626\times10^{-34}\text{ J}\cdot\text{s}(2.998\times10^8\text{ m/s})}{1.89\text{ eV}(1.602\times10^{-19}\text{ J/eV})} = \boxed{656\text{ nm}}$$

(c) $f = \frac{c}{\lambda}$ $$f = \frac{3\times10^8\text{ m/s}}{6.56\times10^{-7}\text{ m}} = \boxed{4.57\times10^{14}\text{ Hz}}$$

P11.35 (a) Lyman series $\frac{1}{\lambda}=R\left(1-\frac{1}{n_i^2}\right)$ $n_i=2,\ 3,\ 4,\ \ldots$

$$\frac{1}{\lambda}=\frac{1}{94.96\times10^{-9}}=\left(1.097\times10^{7}\right)\left(1-\frac{1}{n_i^2}\right) \qquad \boxed{n_i=5}$$

(b) Paschen series: $\frac{1}{\lambda}=R\left(\frac{1}{3^2}-\frac{1}{n_i^2}\right)$ $n_i=4,\ 5,\ 6,\ \ldots$

The shortest wavelength for this series corresponds to $n_i=\infty$ for ionization

$$\frac{1}{\lambda}=1.097\times10^{7}\left(\frac{1}{9}-\frac{1}{n_i^2}\right)$$

For $n_i=\infty$, this gives $\lambda=820$ nm

This is larger than 94.96 nm, so this wave length $\boxed{\text{cannot be associated with the Paschen series}}$.

Balmer series: $\frac{1}{\lambda}=R\left(\frac{1}{2^2}-\frac{1}{n_i^2}\right)$ $n_i=3,\ 4,\ 5,\ \ldots$

$$\frac{1}{\lambda}=1.097\times10^{7}\left(\frac{1}{4}-\frac{1}{n_i^2}\right)$$ with $n_i=\infty$ for ionization, $\lambda_{\min}=365$ nm

Once again the shorter given wavelength $\boxed{\text{cannot be associated with the Balmer series}}$.

P11.36 (a) $v_1=\sqrt{\frac{k_e e^2}{m_e r_1}}$

where $r_1=(1)^2 a_0=0.005\,29\text{ nm}=5.29\times10^{-11}\text{ m}$

$$v_1=\sqrt{\frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(1.60\times10^{-19}\ \text{C}\right)^2}{\left(9.11\times10^{-31}\ \text{kg}\right)\left(5.29\times10^{-11}\ \text{m}\right)}}=\boxed{2.19\times10^{6}\ \text{m/s}}$$

(b) $K_1=\frac{1}{2}m_e v_1^2=\frac{1}{2}\left(9.11\times10^{-31}\ \text{kg}\right)\left(2.19\times10^{6}\ \text{m/s}\right)^2=2.18\times10^{-18}\text{ J}=\boxed{13.6\text{ eV}}$

(c) $U_1=-\frac{k_e e^2}{r_1}=-\frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(1.60\times10^{-19}\ \text{C}\right)^2}{5.29\times10^{-11}\ \text{m}}=-4.35\times10^{-18}\text{ J}=\boxed{-27.2\text{ eV}}$

P11.37 $\Delta E = (13.6\text{ eV})\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$

Where for $\Delta E > 0$ we have absorption and for $\Delta E < 0$ we have emission.

(i) for $n_i = 2$ and $n_f = 5$, $\Delta E = 2.86\text{ eV}$ (absorption)

(ii) for $n_i = 5$ and $n_f = 3$, $\Delta E = -0.967\text{ eV}$ (emission)

(iii) for $n_i = 7$ and $n_f = 4$, $\Delta E = -0.572\text{ eV}$ (emission)

(iv) for $n_i = 4$ and $n_f = 7$, $\Delta E = 0.572\text{ eV}$ (absorption)

(a) $E = \frac{hc}{\lambda}$ so the shortest wavelength is emitted in transition $\boxed{\text{ii}}$.

(b) The atom gains most energy in transition $\boxed{\text{i}}$.

(c) The atom loses energy in transitions $\boxed{\text{ii and iii}}$.

P11.38 We use

$$E_n = \frac{-13.6\text{ eV}}{n^2}.$$

To ionize the atom when the electron is in the n^{th} level,

it is necessary to add an amount of energy given by $E = -E_n = \frac{13.6\text{ eV}}{n^2}$.

(a) Thus, in the ground state where $n = 1$, we have $\boxed{E = 13.6\text{ eV}}$.

(b) In the $n = 3$ level,

$$E = \frac{13.6\text{ eV}}{9} = \boxed{1.51\text{ eV}}.$$

P11.39 (a) $r_2^2 = (0.0529\text{ nm})(2)^2 = \boxed{0.212\text{ nm}}$

(b) $m_e v_2 = \sqrt{\frac{m_e k_e e^2}{r_2}} = \sqrt{\frac{(9.11\times10^{-31}\text{ kg})(8.99\times10^{9}\text{ N}\cdot\text{m}^2/\text{C}^2)(1.60\times10^{-19}\text{ C})^2}{0.212\times10^{-9}\text{ m}}}$

$m_e v_2 = \boxed{9.95\times10^{-25}\text{ kg}\cdot\text{m/s}}$

(c) $L_2 = m_e v_2 r_2 = (9.95\times10^{-25}\text{ kg}\cdot\text{m/s})(0.212\times10^{-9}\text{ m}) = \boxed{2.11\times10^{-34}\text{ kg}\cdot\text{m}^2/\text{s}}$

(d) $K_2 = \frac{1}{2}m_e v_2^2 = \frac{(m_e v_2)^2}{2m_e} = \frac{(9.95\times10^{-25}\text{ kg}\cdot\text{m/s})^2}{2(9.11\times10^{-31}\text{ kg})} = 5.43\times10^{-19}\text{ J} = \boxed{3.40\text{ eV}}$

continued on next page

(e) $U_2 = -\frac{k_e e^2}{r_2} = -\frac{\left(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(1.60\times10^{-19}\ \text{C}\right)^2}{0.212\times10^{-9}\ \text{m}} = -1.09\times10^{-18}\ \text{J} = \boxed{-6.80\ \text{eV}}$

(f) $E_2 = K_2 + U_2 = 3.40\ \text{eV} - 6.80\ \text{eV} = \boxed{-3.40\ \text{eV}}$

P11.40 Starting with $\frac{1}{2}m_e v^2 = \frac{k_e e^2}{2r}$

we have $v^2 = \frac{k_e e^2}{m_e r}$

and using $r_n = \frac{n^2\hbar^2}{m_e k_e e^2}$

gives $v_n^2 = \frac{k_e e^2}{m_e\left(n^2\hbar^2/m_e k_e e^2\right)}$

or $v_n = \frac{k_e e^2}{n\hbar}$.

P11.41 Each atom gives up its kinetic energy in emitting a photon,

so $\frac{1}{2}mv^2 = \frac{hc}{\lambda} = \frac{\left(6.626\times10^{-34}\ \text{J}\cdot\text{s}\right)\left(3.00\times10^8\ \text{m/s}\right)}{\left(1.216\times10^{-7}\ \text{m}\right)} = 1.63\times10^{-18}\ \text{J}$

$v = \boxed{4.42\times10^4\ \text{m/s}}$.

Section 11.6 Context Connection—Changing from a Circular to an Elliptical Orbit

P11.42 The original orbit radius is $r = a = 6.37\times10^6\ \text{m} + 500\times10^3\ \text{m} = 6.87\times10^6\ \text{m}$. The original energy is

$$E_i = -\frac{GMm}{2a} = -\frac{\left(6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2\right)\left(5.98\times10^{24}\ \text{kg}\right)\left(10^4\ \text{kg}\right)}{2\left(6.87\times10^6\ \text{m}\right)} = -2.90\times10^{11}\ \text{J}.$$

We assume that the perigee distance in the new orbit is 6.87×10^6 m. Then the major axis is $2a = 6.87\times10^6\ \text{m} + 2.00\times10^7\ \text{m} = 2.69\times10^7\ \text{m}$ and the final energy is

$$E_f = -\frac{GMm}{2a} = -\frac{\left(6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2\right)\left(5.98\times10^{24}\ \text{kg}\right)\left(10^4\ \text{kg}\right)}{2.69\times10^7\ \text{m}} = -1.48\times10^{11}\ \text{J}.$$

The energy input required from the engine is $E_f - E_i = -1.48\times10^{11}\ \text{J} - \left(-2.90\times10^{11}\ \text{J}\right) = \boxed{1.42\times10^{11}\ \text{J}}$.