SACE Physics Student Workbook Errata

p. 7: (c) Determine the time it takes for the ball to reach the ground once it has reached its maximum height.

p. 18: Q7: $(b) v = v_o + at \rightarrow t = \frac{v - v_o}{a} = t = \frac{0 - 11.5}{-9.80} = 1.17 s$

p. 23: 2. A bird flying at 6.0 ms^{-1} has a kinetic energy of 9.0 J. Determine the mass of the bird.

p. 39: 7(b): $E_K = \frac{1}{2} m v^2 = \frac{1}{2} \times 0.080 \times 0.78^2 = 2.43 \times 10^{-2}\ J$

p. 43: (c) E_k = 67.5 J

p. 44: 16(b)

The speed of B after the collision is: $v = \frac{\sqrt{5^2 + 15^2}\, cm}{0.10} = 1.58\ ms^{-1}$

$p_B(after) = 2 \times 1.20 \times 1.58 = 3.79\, kgms^{-1}$

p. 46: (c) Calculate the magnitude of the force acting on the racing car during the second section of the racetrack.

p. 47: (d) Explain how safety could be improved for racing cars if banked curves were added to the racing track.

p. 58

(b) Plot the missing point from (a) on the graph above and sketch a line of best fit.

p. 65: 1. $a = \frac{v^2}{r} = \frac{\left(\frac{60}{3.6}\right)^2}{4.5} = 61.7\ ms^{-2}$

p. 67: 11(a) $1.94 \times 10^7\ s$

p. 68: 14(c) 1.98×10^{20} N

p. 71: 21(e): $a = \frac{6.67 \times 10^{-11} \times 1.66 \times 10^{22}}{\left(1.16 \times 10^6\right)^2} = 0.82\ ms^{-2}$

p. 72: 24(b): $T = \sqrt{\frac{4\pi^2}{6.67 \times 10^{-11} \times 1.99 \times 10^{30}} \left(1.08 \times 10^{11}\right)^3} = 1.94 \times 10^7\ s$

p. 82

14. (b) Show that the Lorentz factor for Shiro's spaceship is $\gamma = 6.70$.

p. 86

3.

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-\frac{\left(165,000\times10^3\right)^2}{\left(3.00\times10^8\right)^2}}} = 1.20$$

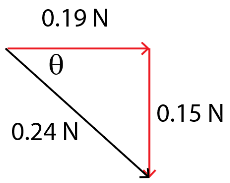
p. 108: 18(b): Hence calculate the magnitude of the force experienced by charge q_1 due to the charge q_2.

p. 111: 20(d): Calculate the magnitude of the net force acting on q_2 due to charges q_1 and q_3.

p. 113-114:8(b),(c)

$$(b)\ F = \frac{1}{4\pi\varepsilon_o}\frac{q_3 q_2}{r^2} = 9.00\times10^9\,\frac{3.0\times10^{-6}\times2.5\times10^{-6}}{0.60^2} = 0.19\ N$$

$$(c)\ \Sigma F = \sqrt{0.15^2+0.19^2} = 0.24\ \text{N}$$



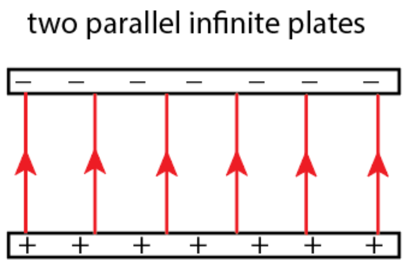
$$\theta = \tan^{-1}\left(\frac{0.15}{0.19}\right) = 38.3^\circ$$

p. 115: 12

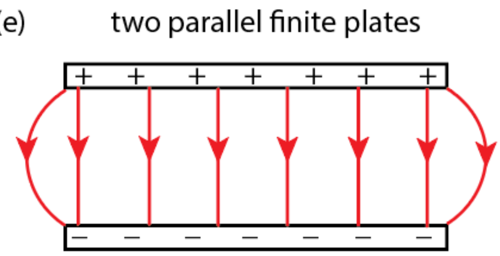
$$\frac{q_1}{r^2} = \frac{q_3}{x^2} \rightarrow x = \sqrt{\frac{q_3}{q_1}r^2} = \sqrt{\frac{3.0\times10^{-6}}{2.0\times10^{-6}}1.2^2} = 1.47\ m$$

p. 116: 15

(d)



(e)



p. 117:19(b)

$$\frac{q_1}{(0.65+x)^2} = \frac{q_2}{x^2} \rightarrow \frac{4.5\times10^{-6}}{(0.65+x)^2} = \frac{2.0\times10^{-6}}{x^2} \rightarrow x = 1.3\ m$$

p. 117: 20

$$(a)\ E = \frac{1}{4\pi\varepsilon_o}\frac{q_1}{r^2} = 9.00\times10^9\frac{8.0\times10^{-6}}{0.50^2} = 2.88\times10^5\ NC^{-1}$$

$$(b)\ E = \frac{1}{4\pi\varepsilon_o}\frac{q_3}{r^2} = 9.00\times10^9\frac{7.0\times10^{-6}}{0.80^2} = 9.84\times10^4\ NC^{-1}$$

$$(c)\ \Sigma E = \sqrt{\left(2.88\times10^5\right)^2 + \left(9.84\times10^4\right)^2} = 3.04\times10^5\ NC^{-1}$$

$$(d)\ F = Eq = 3.04\times10^5 \times 5.0\times10^{-6} = 1.52\ N$$

p. 125

(f) Determine if particle with a charge of $q = -1.60\times10^{-19}$ C and mass of 1.67×10^{-27} kg would reach the upper plate if it entered the electric field at the same position and with the same velocity as the electron.

p. 126

$$(a)\ W = qV = 1.60\times10^{-19}\times150 = 2.40\times10^{-17}\ J$$

p. 134

p. 140

8. A current-carrying conductor…

5.

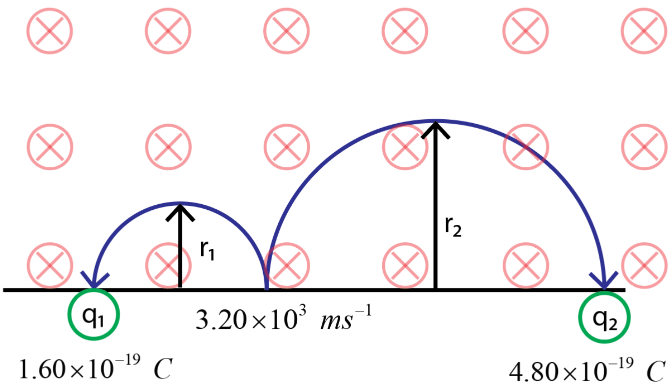
$$(a)\ B = \frac{\mu_0}{2\pi}\frac{I}{r} = 2.00\times10^{-7}\frac{0.12}{3.50\times10^{-3}} = 6.86\times10^{-6}\ T \text{ (into the page)}$$

$$(b)\ B = \frac{\mu_0}{2\pi}\frac{I}{r} = 2.00\times10^{-7}\frac{0.12}{1.20\times10^{-2}} = 2.00\times10^{-6}\ T \text{ (out of the page)}$$

p. 145

14.

Both particles undergo circular motion.



p. 149

$(b)\ F = qvB\sin\theta = 2\times1.60\times10^{-19}\times2.10\times10^{5}\times130\times10^{-6}\sin 40 = 5.62\times10^{-18}\ N$

p. 150

$(c)\ B = \frac{\mu_0}{2\pi}\frac{I}{r} = 2.00\times10^{-7}\frac{1.40}{8.50\times10^{-2}} = 3.29\times10^{-6}\ T$

$F = qvB = 1.60\times10^{-19}\times1.80\times10^{7}\times3.29\times10^{-6} = 9.49\times10^{-18}\ N$

towards the right

p. 162

9.

$(a)\ E_K = \frac{q^2B^2r^2}{2m} \rightarrow B = \sqrt{\frac{2mE_K}{q^2r^2}}$

$B = \sqrt{\frac{2\times1.67\times10^{-27}\times1.82\times10^{8}\times1.60\times10^{-19}}{\left(1.60\times10^{-19}\right)^2(0.750)^2}} = 2.60\ T$

$(b)\ T = \frac{2\pi m}{qB} = \frac{2\pi\times1.67\times10^{-27}}{1.60\times10^{-19}\times2.60} = 2.52\times10^{-8}\ s$

(c) Each time the proton passes through the gap between the dees it gains 32,500 eV.

The proton leaves with 1.82×10^{8} eV.

Therefore, it crosses the field $\frac{1.82\times10^{8}}{32{,}500} = 5600$ times.

Therefore, the proton completes $\frac{5600}{2} = 2800$ complete circles within the cyclotron.

Therefore it takes $2.58\times10^{-8}\times2800 = 7.06\times10^{-5}\ s$ for the proton to leave the cyclotron.

p. 171

(a) Explain how the graph above indicates that an alternating current is produced by the generator.

p. 174

1.

If there is a changing magnetic flux through N closed loops then the induced emf in the loop is given by $\varepsilon = N\frac{\Delta\Phi}{\Delta t}$

5 $(c)\ \varepsilon = N\frac{\Delta\Phi}{\Delta t} \rightarrow \varepsilon = \frac{8.70\times10^{-5}}{0.12\times10^{-3}} = 0.725\ V$

5 $(d)\ \varepsilon = 4\frac{8.70\times10^{-5}}{0.12\times10^{-3}} = 2.90\ V$

$6\,(b)\ \varepsilon = N\dfrac{\Delta\Phi}{\Delta t} \rightarrow \varepsilon = \dfrac{1.98\times10^{-2}}{56\times10^{-6}} = 354\ V$

6(c)##last sentence should read## Therefore, the current is clockwise.

p. 175

$7\,(c)\ \varepsilon = N\dfrac{\Delta\Phi}{\Delta t} \rightarrow \varepsilon = \dfrac{5.27\times10^{-4}}{15.0\times10^{-3}} = 0.0351\ V$

p. 177

12(c): $\Delta\Phi = B\Delta A \rightarrow \Delta A = \dfrac{\Delta\Phi}{B} = \dfrac{0.15}{2.30} = 0.065\ Wb$

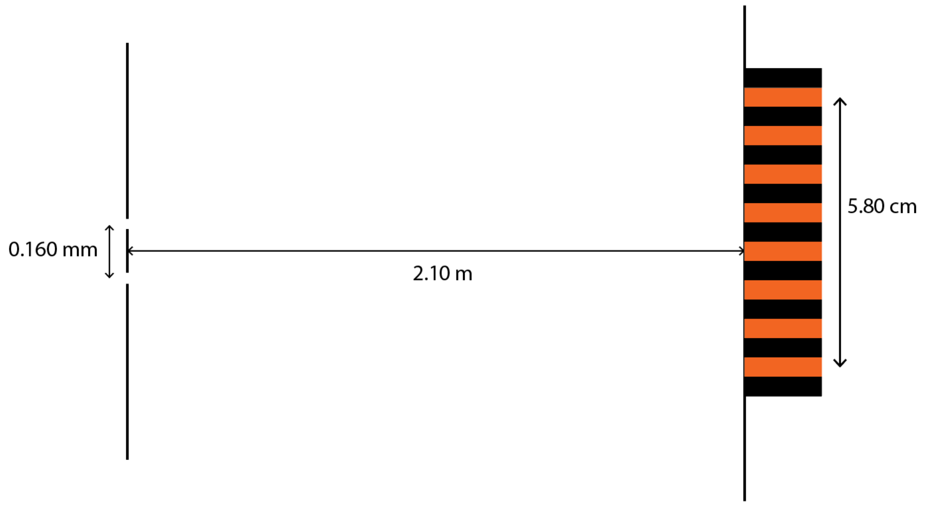
p. 186

10. A two-slit experiment was conducted with a laser and slits that were separated by 1.20 mm. The interference pattern was observed on a screen that was positioned 5.60 m from the slits. The following measurement was taken on the screen.

p. 188

12. Explain why a series of dark and light fringes are observed on a screen in a two-slit experiment.

p. 192



p. 193

17 (c): The first maximum is observed at an angle of 20.5°.

p. 194

(b) Calculate the separation between the slits of the diffraction grating.

(c) White light is composed of all wavelengths in the visible spectrum.

Calculate the angular positions of the first order maxima of the following:

(i) red (640 nm)

(ii) orange (600 nm)

(iii) yellow (580 nm)

(iv) green (510 nm)

(v) blue (480 nm)

(vi) violet (410 nm)

p. 198

1(c): $v = f\lambda \rightarrow \lambda = \frac{v}{f} = \frac{3.00 \times 10^8}{1235 \times 10^6} = 0.243 \text{ m}$

2(a): $v = f\lambda \rightarrow f = \frac{v}{\lambda} = \frac{3.00 \times 10^8}{34.5} = 8.70 \times 10^6 \text{ Hz}$

p. 197

White light consists of wavelengths from 400 nm to 750 nm.

White light is incident on a transmission diffraction grating with 420 lines per mm. White light is then incident on a transmission diffraction grating with 600 lines per mm. Determine if there is any overlap in the angular spread of first order maxima for the two diffraction gratings.

p. 199

6(b): $v = f\lambda \rightarrow f = \frac{v}{\lambda} = \frac{3.00 \times 10^8}{1440} = 2.08 \times 10^5 \text{ Hz}$

p. 200

10:

$$(a)\ 7\Delta y = 2.00\times10^{-2}\ m \therefore \Delta y = \frac{2.00\times10^{-2}}{7} = 2.86\times10^{-3}\ m$$

$$(b)\ \Delta y = \frac{\lambda L}{d} \rightarrow \lambda = \frac{d\Delta y}{L} = \frac{1.20\times10^{-3}\times2.86\times10^{-3}}{5.60} = 6.13\times10^{-7}\ m$$

$$(c)\ v = f\lambda \rightarrow f = \frac{v}{\lambda} = \frac{3.00\times10^{8}}{6.13\times10^{-7}} = 4.90\times10^{14}\ Hz$$

$$(d)\ m\lambda = d\sin\theta \rightarrow \theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{3\times6.13\times10^{-7}}{1.20\times10^{-3}}\right) = 0.088^{\circ}$$

p. 201

14(a):

$$m\lambda = d\sin\theta \rightarrow \lambda = \frac{d\sin\theta}{m}$$

$$d = \frac{1}{600\times10^{3}} = 1.67\times10^{-6}\ m \therefore \lambda = \frac{1.67\times10^{-6}\sin 14}{1} = 4.03\times10^{-7}\ m$$

15:

$$(a)\quad m\lambda = d\sin\theta \rightarrow m = \frac{d\sin\theta}{\lambda};\text{let }\sin\theta = 1; d = \frac{1}{500\times10^{3}} = 2.00\times10^{-6}\ m$$

$$m = \frac{2.00\times10^{-6}}{6.30\times10^{-7}} = 3.17 \text{ therefore } m = 3$$

$$(b)\ m\lambda = d\sin\theta \rightarrow \theta = \sin^{-1}\left(\frac{m\lambda}{d}\right)$$

$$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{1\times6.30\times10^{-7}}{2.00\times10^{-6}}\right) = 18.4^{\circ}$$

$$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{2\times6.30\times10^{-7}}{2.00\times10^{-6}}\right) = 39.1^{\circ}$$

$$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{3\times6.30\times10^{-7}}{2.00\times10^{-6}}\right) = 70.9^{\circ}$$

p. 203

18.

(a) Each wavelength diffracts at a different angle, with red light having the greatest diffraction angle and violet the lowest. Since white light is composed of all wavelengths, the full spectrum is observed.

$(b)\ m\lambda = d\sin\theta \rightarrow \theta = \sin^{-1}\left(\frac{m\lambda}{d}\right); d = \frac{1}{650\times10^{3}} = 1.54\times10^{-6}\ m$

(c)

$i)\ \theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{1\times640\times10^{-9}}{1.54\times10^{-6}}\right) = 24.6^{\circ}$

$ii)\ \theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{1\times600\times10^{-9}}{1.54\times10^{-6}}\right) = 22.9^{\circ}$

$iii)\ \theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{1\times580\times10^{-9}}{1.54\times10^{-6}}\right) = 22.1^{\circ}$

$iv)\ \theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{1\times510\times10^{-9}}{1.54\times10^{-6}}\right) = 19.3^{\circ}$

$v)\ \theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{1\times480\times10^{-9}}{1.54\times10^{-6}}\right) = 18.2^{\circ}$

$vi)\ \theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{1\times410\times10^{-9}}{1.54\times10^{-6}}\right) = 15.4^{\circ}$

p. 210

(d) Sketch a line of best fit if the target of the photoelectric effect apparatus was replaced with a metal with a work function of 2.10 eV.

p. 222

1.

$(a)\ v = f\lambda \therefore \lambda = \frac{v}{f} = \frac{3.00\times10^{8}}{6.70\times10^{11}} = 4.48\times10^{-4}\ m$

$E = hf = 6.63\times10^{-34}\times4.48\times10^{-4} = 2.97\times10^{-22}\ J$

$p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{4.48\times10^{-4}} = 1.48\times10^{-30}\ sN$

$(b)\ v = f\lambda \therefore \lambda = \frac{v}{f} = \frac{3.00\times10^{8}}{2.15\times10^{14}} = 1.40\times10^{-6}\ m$

$E = hf = 6.63\times10^{-34}\times2.15\times10^{14} = 1.43\times10^{-19}\ J$

$p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{1.40\times10^{-6}} = 4.74\times10^{-28}\ sN$

p. 224

$$E_{K_{\max}} = eV_s \therefore \frac{eV_s}{f} = h \rightarrow \frac{V_s}{f} = \frac{h}{e}$$

$$\frac{h}{e} = 4.0\times10^{-15} \rightarrow h = 4.0\times10^{-15}\times1.60\times10^{-19} = 6.4\times10^{-34}\ Js$$

p. 225

10(c):

$$(c)\ f_{\max} = \frac{e\Delta V}{h} = \frac{1.60\times10^{-19}\times0.45\times10^{6}}{6.63\times10^{-34}} = 1.09\times10^{20}\ Hz$$

11(c):

$$(c)\ f_{\max} = \frac{e\Delta V}{h} \to \Delta V = \frac{hf_{\max}}{e} = \frac{6.63\times10^{-34}\times1.09\times10^{21}}{1.60\times10^{-19}} = 4.52\times10^{6}\ V$$

p. 227

16(a): $(a)\ f_{\max} = \frac{e\Delta V}{h} \to \Delta V = \frac{hf_{\max}}{e} = \frac{6.63\times10^{-34}\times1.37\times10^{18}}{1.60\times10^{-19}} = 5677\ V$

17(a): $(a)\ p = \frac{h}{\lambda} \to mv = \frac{h}{\lambda} \to \lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times0.76\times3.00\times10^{8}} = 3.19\times10^{-12}\ m$

p. 228

22(d):

(d) At the speed calculated in (b), the electrons exhibit wave-like properties. Since the spacing between the slits is comparable to the de Broglie wavelength of the electrons, diffraction and interference effects occur. Therefore, a series of maxima and minima are observed.

p. 233

(b) Determine the wavelength of the photon that is needed to cause an upward transition from n = 1 to n = 3.

p. 229

$$(d)\ m\lambda = d\sin\theta \to d = \frac{m\lambda}{\sin\theta} = \frac{1\times1.52\times10^{-10}}{\sin 11.6} = 7.57\times10^{-10}\ m$$

p. 246

3:

(c) $E = -0.54 - -3.40 = 2.86\ eV = 4.58\times10^{-19}\ J$

$$E = hf \to f = \frac{E}{h} = \frac{4.58\times10^{-19}}{6.63\times10^{-34}} = 6.90\times10^{14}\ Hz$$

p. 246/247

5.

$(a)\ E = -2.30 - -9.40 = 7.10\ eV = 1.14\times10^{-18}\ J$

$E = hf \rightarrow f = \dfrac{E}{h} = \dfrac{1.14\times10^{-19}}{6.63\times10^{-34}} = 1.71\times10^{15}\ Hz$

$v = f\lambda \rightarrow \lambda = \dfrac{v}{f} = \dfrac{3.00\times10^{8}}{1.71\times10^{15}} = 1.75\times10^{-7}\ m$

$(b)\ \ E = 15.60 - 4.70 = 10.90\ eV = 1.74\times10^{-18}\ J$

$E = hf \rightarrow f = \dfrac{E}{h} = \dfrac{1.74\times10^{-18}}{6.63\times10^{-34}} = 2.63\times10^{15}\ Hz$

$v = f\lambda \rightarrow \lambda = \dfrac{v}{f} = \dfrac{3.00\times10^{8}}{2.63\times10^{15}} = 1.14\times10^{-7}\ m$

$(c)\ E = 0 - -15.60 = 15.60\ eV = 2.50\times10^{-18}\ J$

$E = hf \rightarrow f = \dfrac{E}{h} = \dfrac{2.50\times10^{-18}}{6.63\times10^{-34}} = 3.76\times10^{15}\ Hz$

$v = f\lambda \rightarrow \lambda = \dfrac{v}{f} = \dfrac{3.00\times10^{8}}{3.76\times10^{14}} = 7.97\times10^{-8}\ m$

p. 247

6

The electron in a hydrogen atom at room temperature is in the ground state. Therefore, all transitions are outside the visible region as all transitions to the ground state are in the UV region of the spectrum.

7(b):

$(b)\ \ E = -8.86 - -20.90 = 12.04\ eV = 1.93\times10^{-18}\ J$

$E = hf \rightarrow f = \dfrac{E}{h} = \dfrac{1.93\times10^{-18}}{6.63\times10^{-34}} = 2.91\times10^{15}\ Hz$

$v = f\lambda \rightarrow \lambda = \dfrac{v}{f} = \dfrac{3.00\times10^{8}}{2.83\times10^{15}} = 1.03\times10^{-7}\ m$

p. 248

8(b):

$(b)\ E = -0 - -1.04 = 1.04\ eV = 1.66\times10^{-19}\ J$

$E = hf \rightarrow f = \dfrac{E}{h} = \dfrac{1.66\times10^{-19}}{6.63\times10^{-34}} = 2.51\times10^{14}\ Hz$

$v = f\lambda \rightarrow \lambda = \dfrac{v}{f} = \dfrac{3.00\times10^{8}}{2.51\times10^{14}} = 1.20\times10^{-6}\ m$

9(a):

When an electron in an atom absorbs a photon and transitions to an electron energy level that is two or more levels higher than its current electron energy level, it may return to its original level by transitioning down two or more electron energy levels separately. When this occurs, multiple photons are emitted. This process is called fluorescence.

p.249

10:

10.

$$v = f\lambda \rightarrow f = \frac{v}{\lambda} = \frac{3.00\times10^{8}}{93.47\times10^{-9}} = 3.21\times10^{15}\ Hz$$

$$E = hf = 6.63\times10^{-34}\times3.21\times10^{15} = 2.13\times10^{-18}\ J = 13.30\ eV$$

$$\text{Therefore, } -x - -18.50 = 13.30 \Rightarrow x\ =\ 18.50 - 13.30 = 5.20$$

$n = 3$ to $n = 2$

$$E = -10.60 - -4.60 = 5.40\ eV = 8.64\times10^{-19}\ J$$

$$E = hf \rightarrow f = \frac{E}{h} = \frac{8.64\times10^{-19}}{6.63\times10^{-34}} = 1.30\times10^{15}\ Hz$$

$$v = f\lambda \rightarrow \lambda = \frac{v}{f} = \frac{3.00\times10^{8}}{1.30\times10^{15}} = 2.30\times10^{-7}\ m$$

$n = 2$ to $n = 1$

$$E = -18.50 - -10.60 = 7.90\ eV = 1.26\times10^{-18}\ J$$

$$E = hf \rightarrow f = \frac{E}{h} = \frac{1.26\times10^{-18}}{6.63\times10^{-34}} = 1.91\times10^{15}\ Hz$$

$$v = f\lambda \rightarrow \lambda = \frac{v}{f} = \frac{3.00\times10^{8}}{1.90\times10^{15}} = 1.57\times10^{-7}\ m$$

p.250

11(b):

(b)

$n = 3$ to $n = 1$

$$E = -73.60 - -8978.9 = 8905.3\ eV = 1.42\times10^{-15}\ J$$

$$E = hf \rightarrow f = \frac{E}{h} = \frac{1.42\times10^{-15}}{6.63\times10^{-34}} = 2.15\times10^{18}\ Hz$$

$n = 2$ to $n = 1$

$$E = -951.0 - -8978.9 = 8027.9\ eV = 1.28\times10^{-15}\ J$$

$$E = hf \rightarrow f = \frac{E}{h} = \frac{1.28\times10^{-15}}{6.63\times10^{-34}} = 1.94\times10^{18}\ Hz$$

p. 252

15.

First, a, b, c, and d need to be determined.

$a:$

$$v = f\lambda \rightarrow f = \frac{v}{\lambda} = \frac{3.00\times10^{8}}{605\times10^{-9}} = 4.96\times10^{14}\ Hz$$

$$E = hf = 6.63\times10^{-34}\times4.96\times10^{14} = 3.29\times10^{-19}\ J = 2.05\ eV$$

$$a - 0.12 = 2.05 \rightarrow a = 2.17$$

$b:$

$$v = f\lambda \rightarrow f = \frac{v}{\lambda} = \frac{3.00\times10^{8}}{540\times10^{-9}} = 5.56\times10^{14}\ Hz$$

$$E = hf = 6.63\times10^{-34}\times5.56\times10^{14} = 3.68\times10^{-19}\ J = 2.30\ eV$$

$$b - 2.17 = 2.30 \rightarrow b = 4.47$$

$c:$

$$v = f\lambda \rightarrow f = \frac{v}{\lambda} = \frac{3.00\times10^{8}}{480\times10^{-9}} = 6.25\times10^{14}\ Hz$$

$$E = hf = 6.63\times10^{-34}\times6.25\times10^{14} = 4.14\times10^{-19}\ J = 2.59\ eV$$

$$c - 4.47 = 2.59 \rightarrow c = 7.06$$

$d:$

$$v = f\lambda \rightarrow f = \frac{v}{\lambda} = \frac{3.00\times10^{8}}{415\times10^{-9}} = 7.23\times10^{14}\ Hz$$

$$E = hf = 6.63\times10^{-34}\times7.23\times10^{14} = 4.79\times10^{-19}\ J = 3.00\ eV$$

$$d - 7.06 = 2.99 \rightarrow d = 10.06$$

Therefore, n=2 to n=1

$$E = -10.06 - -19.80 = 9.74\ eV = 1.56\times10^{-18}\ J$$

$$E = hf \rightarrow f = \frac{E}{h} = \frac{1.56\times10^{-18}}{6.63\times10^{-34}} = 2.35\times10^{15}\ Hz$$

$$v = f\lambda \rightarrow \lambda = \frac{v}{f} = \frac{3.00\times10^{8}}{2.35\times10^{15}} = 1.28\times10^{-7}\ m$$

p. 262

12. Two electrons annihilate to form two photons.