Electromagnetic Radiation Section (Astro 18) – Answer Key

1) $$\nu = \frac{c}{\lambda} = \frac{3*10^8 m/s}{21cm} = \frac{3*10^8 m/s}{21cm\frac{(1m)}{(100cm)}} = \frac{3*10^8 m/s}{0.21m} = 1427583133Hz \;\; or \;\; 1.4276GHz$$

$$E = h\nu = (6.626068*10^{-34}\frac{m^2 kg}{s})(1427583133Hz) = 9.5*10^{-25} Joules$$

2) Stefan-Boltzman Equation: $\frac{Emitted\ Power}{Surf\ aceArea} = \sigma T^4$

$$\frac{Emitted\ Power}{Surf\ aceArea} = \frac{4*10^{26}Watts}{4\pi r^2} = \frac{4*10^{26}Watts}{4\pi(7*10^8 m)^2} = 6*10^7\frac{Watts}{m^2}$$

$$6*10^7\frac{W}{m^2} = \sigma T^4 --> T = \sqrt[4]{\frac{6*10\ \frac{Watts}{m^2}}{5.7*10^{-8}\frac{W}{m^2K^4}}} = 6000°Kelvin$$

$$\lambda_{\max} = \frac{b}{T} = \frac{2.8977*10^{-3}mK}{6000K} = 5*10^{-6}m$$

3) $(98°F - 32°F)(5/9) \approx 37°C$ $\qquad 37°C + 273 = 310°K$

$$\lambda_{\max} = \frac{b}{T} = \frac{2.8977*10^{-3}mK}{310K} = 10\mu m$$

4) $$z = \frac{v}{c} --> v = zc = \frac{(121.9nm - 121.6nm)}{121.6nm}(3*10^8\frac{m}{s}) = 740{,}000\frac{m}{s}\ \ away\ \ f\,romus$$

$$z = \frac{v}{c} --> v = zc = \frac{(122.9nm - 121.6nm)}{121.6nm}(3*10^8\frac{m}{s}) = 3{,}207{,}000\frac{m}{s}\ \ away\ \ f\,romus$$

5) $z = \frac{\lambda_{obs} - \lambda_{emit}}{\lambda_{emit}} = \frac{3962A - 3933.7A}{3933.7A} = 0.0071$

$v = zc = (0.0071)(3*10^8 m/s) = 2{,}128{,}526 m/s$

$v = H_o d --> d = \frac{v}{H_o} = \frac{2{,}128{,}526 m/s}{70\frac{(km/s)}{Mpc}} = 30Mpc = 97{,}849{,}088 light\ years$

6) $M_{star} = 1.06 M_{sun} = 1.06(2*10^{30} kg) = 2.12*10^{30} kg$

$Period = 4.23 days = (4.23 days)(\frac{24hrs}{1day})(\frac{3600\sec}{1hr}) = 3.65*10^5 \sec onds$

$$r = \sqrt[3]{\frac{G*M_{star}*Period^2}{4\pi^2}} = \sqrt[3]{\frac{(6.67*10^{-11}\frac{m^3}{kg\cdot s^2})*(2.12*10^{30} kg)*(3.65*10^5 \sec)^2}{4\pi^2}} = 7.81*10^9 m$$

$r = (7.81*10^9 m)(\frac{1AU}{1.5*10^{11} m}) = 0.052AU$

Conservation of momentum: $M_{star}V_{star} = M_{planet}V_{planet} --> M_{planet} = \frac{M_{star}V_{star}}{V_{planet}}$

Know $M_{star} = 2.12*10^{30} kg\ \ and\ \ V_{star} = 57 m/s$ from observations, need V_{planet}

From orbital eqn:

$$V_{planet} = \sqrt{\frac{G*M_{star}}{r}} = \sqrt{\frac{(6.67*10^{-11}\frac{m^3}{kg\cdot s})*(2.12*10^{30} kg)}{7.81*10^9 m}} = 134{,}587 m/s$$

So: $M_{planet} = \frac{(2.12*10^{30} kg)(57 m/s)}{134{,}587 m/s)} = 8.97*10^{26} kg$

$M_{planet} = 8.97*10^{26} kg*(\frac{1M_{earth}}{6*10^{24} kg}) = 150 M_{earth}$