ECE235 HW1, Harry Luo

3.17

By Stefan-Boltzmann Law, set total power $P = \kappa R$ and initial tempreture T_0 , we have

$$R = \sigma T^4 \Rightarrow P = \kappa \sigma T^4$$
$$\frac{P'}{P} = \frac{T'^4}{T^4} = \frac{(2T_0)^4}{T_0^4} = 16) \tag{1}$$

$\boxed{\text{Power increases by a factor of 16.}}$

3.19

- (a)

Let initial tempreture be T_0 and the new tempreture be T'. By Wien's Law, we have

$$\lambda T_0 = 2.898e^{-3}\ m \cdot K \quad \Rightarrow T_0 = \frac{2.898e\text{-}3}{27e\text{-}6})K = 107.33K. \tag{2}$$

Using Stefan-Boltzmann Law to find the new tempreture.

$$\frac{P'}{P} = \frac{(T')^4}{T_0^4} = 2 \quad \Rightarrow T' = \sqrt[4]{2T_0^4} = \sqrt[4]{2 \times 107.33^4} = \boxed{127.63K} \tag{3}$$

- (b) By Wien's law,

$$\lambda = \frac{2.898e\text{-}3}{T'} = \frac{2.898e\text{-}3}{127.63}m = \boxed{22.7\mu m} \tag{4}$$

3.24

- (a)

Energy quantization shows:

$$E = hf = \frac{hc}{\lambda}. \tag{5}$$

Given $\lambda \in (380, 750)$nm,

$$\frac{hc}{750\text{nm}} < E < \frac{hc}{380\text{nm}} \quad \Rightarrow \boxed{E \in (1.653, 3.542)\text{eV}} \tag{6}$$

- (b)

$$E = hf = 4.136 \times 10^{-15} \times 100 \times 10^6\ \text{eV} = \boxed{4.136 \times 10^-7\ \text{eV}} \tag{7}$$

3.25

- (a)

By the photoelectric effect equation, at therashold wavelength, we have

$$\Phi = hf_t = h\frac{c}{\lambda_t} \quad \Rightarrow \lambda_t = \frac{hc}{\Phi} = \frac{1.24e\text{-}6}{4.87}m = \boxed{2.546e\text{-}7m} \tag{8}$$

- (b)

As suggested on Piazza, we use mid-point approximation to approximate the integrated energy density of sunlight from 0nm to 254.6nm by using the intensity at $254.6/2 = 127.3$ nm as constant density:

$$u(127.3\text{nm}) \times (254.6\ \text{nm}) = \frac{8\pi hc(127.3e\text{-}9m)^{-5}}{e^{hc/(k\times 5800K\times 127.3e\text{-}9m)} - 1} \times (254.6e\text{-}9m) \approx 1.23e\text{-}4 \quad J/m^3 \tag{9}$$

Energy density is thus approximately

$$R' = \frac{c}{4}(1.23e\text{-}4) \quad J/m^3 \tag{10}$$

Total energy is given by

$$R = \sigma T^4 = \sigma \times 5800K^4 \approx 6.42e7 \quad W/m^2 \tag{11}$$

Thus the maximal fractional power is

$$\boxed{\frac{R'}{R} \approx 1.4e\text{-}4} \tag{12}$$

3.26

- (a)

Using the photoelectric equation,we can find threshold freq and wavelength, f_t, λ_t as follows,

$$\begin{aligned} \Phi = hf_t &= \frac{hc}{\lambda_t} \\ \Rightarrow f_t = \frac{\Phi}{h} &= \frac{1.9eV}{4.136e\text{-}15eV\cdot s} = \boxed{4.59e4\ \ \text{Hz}}, \\ \lambda_t = \frac{hc}{\Phi} &= \frac{1240\ \text{eV}\cdot\text{nm}}{1.9\ \text{eV}} = \boxed{653\ \text{nm}} \end{aligned} \tag{13}$$

- (b,c,d) The stopping potential can be found as follows,

$$eV_0 = \frac{hc}{\lambda} - \Phi \quad \Rightarrow V_0 = \frac{hc}{\lambda e} - \frac{\Phi}{e}. \tag{14}$$

For $\lambda = 300$nm:

$$V_0 = \frac{1240\ \text{eV}\cdot\text{nm}}{e\times 300e\text{-}9m} - \frac{1.9\ \text{eV}}{e} = \boxed{2.23V} \tag{15}$$

For $\lambda = 400$ nm,

$$V_0 = \frac{1}{e}\frac{1240\text{eV}\cdot\text{nm}}{400\text{nm}} - 1.9\text{eV} = \boxed{1.20V} \tag{16}$$

3.28

- (a)

$$f_t = \frac{\Phi}{h} = \frac{4.22\ \text{eV}}{4.14e\text{-}15\ \text{eV}\cdot s} = \boxed{1.02\times 10^{15}\ \text{Hz}} \tag{17}$$

- (b)

$$f = \frac{c}{\lambda} = \frac{3e8}{560e_{\text{-}9}}\ \text{Hz} = \boxed{5.36\times 10^{14}\ \text{Hz} < f_t} \tag{18}$$

Frequency is less than the threshold frequency, so **no** photoelectrons are emitted.

3.31

Consider the photoelectric effect equation for $n = 60$ photons,

$$E = n\frac{hc}{\lambda} = \frac{60 \times 6.63e\text{-}34 \times 3e8}{550e\text{-} - 9} J = \boxed{2.17e\text{-}17J}. \tag{19}$$

3.32

- (a)

$$\Phi = \frac{hc}{\lambda} = \frac{1240}{653} \text{ eV} = \boxed{1.9 \text{ eV}} \tag{20}$$

- (b)

$$E_k = \frac{hc}{\lambda} - \Phi = \frac{1240}{300} \text{ eV} - 1.9 \text{ eV} = \boxed{2.23 \text{ eV}} \tag{21}$$

3.42

Consider the stopping potential function for both cases, we have

$$\begin{aligned} eV &= \frac{hc}{\lambda} - \Phi \\ \Rightarrow &\begin{cases} V_1 = \dfrac{1}{e}\dfrac{hc}{\lambda_1} - \Phi \\ V_2 = \dfrac{1}{e}\dfrac{hc}{\lambda_2} - \Phi \end{cases} \end{aligned} \tag{22}$$

Where $V_1 = 0.52V$, $\lambda_1 = 450$ nm; $V_2 = 1.9V$, $\lambda_2 = 300$ nm.

Solving Equation 22 for h and Φ:

$$\begin{cases} 0.52V = \dfrac{1}{e}\dfrac{hc}{450\text{nm}} - \Phi \\ 1.9V = \dfrac{1}{e}\dfrac{hc}{300\text{nm}} - \Phi \end{cases} \Rightarrow \boxed{\begin{cases} h = 6.6376e\text{-}34J \cdot s \quad \text{(a good approximation!)} \\ \Phi = 2.24 \text{ eV} \end{cases}} \tag{23}$$