

1. You are in a Vagon Spaceship taking a thermal physics exam and listening to Vagon poetry in the background. The room is a comfortable 25.00 C° environment. Your surface area is approximately 2.000m². Your surface emissivity is =1.000 (Goth Attire). (you may assume your shape is spherical) (32 pts)
- a. What radiative POWER of light do you receive from the surroundings (assume all objects are perfect blackbody radiator/absorbers)?

$$\sigma = 5.6705 \times 10^{-8} \frac{\text{W}}{\text{m}^2 \text{K}^4}$$
$$T = 298 \text{ K}$$
$$P = I A = (\sigma T^4) 2 \text{ m}^2$$
$$= 894 \text{ W}$$

- b. What Power are you radiating at your human body temperature of 37.00 C°? And what is the net power flow in or out (two results)?

$$T = 310 \text{ K}$$

$$P_{\text{out}} = 1047.4 \text{ watts}$$

like above

$$P_{\text{net}} = 153.4 \text{ watts}$$

I am a bright Lightbulb!

- c. You decide that you are more comfortable leaving the room and enter the dark vacuum of space (very far from any bright objects), what total power will you be radiating (you may approx. the temp of space as zero)?

we had # - output
- no input

$$P = 1047.4 \text{ Watts}$$

// "Space is cold" ...

$$\lambda_p = \frac{2.898 \text{ mmK}}{298 \text{ K}} = 9.72 \times 10^{-6}$$

- d. Your good friend has brought you a blanket which allows only a narrow band of emission from you to escape---at your peak wavelength plus or minus 0.5nm. What is your power emission now?

$$U_\lambda d\lambda = \frac{8\pi hc}{\lambda^5} \frac{d\lambda}{\left[\exp\left(\frac{hc}{\lambda kT}\right) - 1 \right]}$$

$$= 4.025 \times 10^{-10} \text{ J/m}^3$$

$$d\lambda = 10^{-9} \text{ m}$$

$$h = 6.626 \times 10^{-34} \text{ J s}$$

$$k = 1.38 \times 10^{-23} \text{ J/K}$$

$$\frac{hc}{\lambda kT} = 4.97 \text{ at peak.}$$

$$P = \underbrace{\quad} * \frac{c}{4} * A = 0.060 \text{ Watts}$$

I keep warm
 - No Air!

2. An electron with 1,200,000 eV of kinetic energy strikes a metal surface resulting in the emission of a photon. Assume all the kinetic energy was transferred to the photon. (24 pts)
- a. What is the name for this process, and what is the wavelength and frequency of the photon?

Bremstrahlung $E = h\nu$

$$\nu = \frac{1200000 \text{ eV}}{4.136 \times 10^{-15} \text{ eV} \cdot \text{s}}$$

$$= 2.90 \times 10^{20} \text{ Hz}$$

$$\lambda = \frac{c}{\nu} = 1.03 \times 10^{-12} \text{ m}$$

- b. What is the initial incident momentum of the electron, and if the photon (energy given in part a) is emitted back along the electron path---what is the final momentum of the photon? Is all the momentum accounted for---if not, where is it (and how much)?

$$E^2 = p^2 c^2 + E_0^2$$

$$p_{e_i} = \frac{\sqrt{(0.511 + 1.2)^2 - 0.511^2}}{c}$$

$$= 1.633 \frac{\text{MeV}}{c}$$

$$p_{\text{photon}} = \sim 1.200 \frac{\text{MeV}}{c}$$

The remaining $p = 2.833 \frac{\text{MeV}}{c}$ goes to target metal.

~ No energy really - why?

- c. The photon with the same given energy, now passes onto a thin gold foil and scatters off an electron. This is a different process now. Determine the wavelength of the scattered photon for angles of 0, 90, and 180°.

$$\frac{h}{mc} = 2.426 \text{ pm}$$

$$\Delta\lambda = \frac{h}{mc} (1 - \cos\theta)$$

$$\Delta\lambda_{180} = 4.852 \text{ pm}$$

$$\Delta\lambda_{90} = 2.426 \text{ pm}$$

$$\Delta\lambda_0 = 0$$

$$\lambda_0 = 1.03 \times 10^{-12} \text{ m}$$

$$\lambda_{\text{scat } 180} = 5.882 \text{ pm}$$

$$\lambda_{\text{scat } 90} = 3.456 \text{ pm}$$

$$\lambda_{\text{scat } 0} = 1.03 \text{ pm}$$

3. In a given photoelectric effect experiment you make the following measurements while changing the retarding voltage very slowly on a single stage detector (24 pts)

Data Point	Retarding Potential magnitude(Volts)	Photocurrent (nA)	Wavelength
1	1.32994	0.00000	450nm
2	1.26073	0.00000	450nm
3	1.25720	-0.00002	450nm
4	1.24361	-0.0062	450nm
5	0.6304	-2.5410	450nm
6	0.3578	-2.9538	450nm
7	1.42345	0.00000	480nm
8	0.98475	0.00000	480nm
9	1.01029	-0.00010	500nm
10	0.98332	-0.00040	500nm
11	0.4924	-1.7637	500nm
12	0.2451	-3.1559	500nm
13	0.75886	0.00000	550nm
14	0.3764	-1.7673	550nm
15	0.57062	0.00000	600nm
16	0.2703	-0.81432	600nm
17	0.62349	0.00000	650nm
18	0.41125	0.00000	650nm
19	0.41079	-0.00010	650nm
20	0.40129	-0.00032	650nm
21	0.2105	-0.40743	650nm

- a) Select two data points that you will use to make a rough quick analysis of the experiment. Explain BRIEFLY why you are selecting this data for the photoelectric effect. There are only two correct data points here.

Your data points 2 & 18

For a part
reach $i = 0$

- b) Use your two data points you selected to determine an experimental value for Planck's constant in appropriate units.

$$eV_2 = 1.26073 \text{ eV} \quad \lambda_2 = 450 \text{ nm} \quad \nu_2 = 6.67 \times 10^{14} \text{ Hz}$$

$$eV_{18} = 0.41125 \text{ eV} \quad \lambda_{18} = 650 \text{ nm} \quad \nu_{18} = 4.62 \times 10^{14} \text{ Hz}$$

$$h = \frac{(1.26073 - 0.41125) \text{ eV}}{(6.67 - 4.62) \times 10^{14} \text{ Hz}} = 4.14 \times 10^{-15} \text{ eV s}$$

$$= 6.64 \times 10^{-34} \text{ J s}$$

- c) Determine the work function of the metal (you select appropriate units)?

$$eV_0 = h\nu - \Phi \quad \text{Pick Point}$$

$$\Phi = 4.14 \times 10^{-15} \text{ eV s} \times 6.67 \times 10^{14} \text{ Hz} - 1.26073$$

$$= 1.50 \text{ eV}$$

- d) For one of **your** data points DESCRIBE HOW TO determine the maximum possible speed of the ejected photoelectron (m/s)? Tell me precisely and clearly how to do this---make sure I know how to solve for speed, have clear labels in your equation, and indicate the numbers going into it---DO NOT BOTHER TO CRUNCH OUT THE NUMBER.

Equation: $\frac{1}{2} m_e v^2 = \# eV_0$

Known numbers:

$$v = 6.66 \times 10^5 \text{ m}$$

$$m_e = 9.11 \times 10^{-31} \text{ kg}$$

$$e = 1.602 \times 10^{-19} \text{ C}$$

$$\# eV_0 = 1.26073 \text{ eV}$$

Convert to J

Classical!

4. A beam of light enters a military grade fiber optic. The initial power of the beam is 200milliWatts. The absorption coefficient (attenuation constant) is 0.005/m. The wavelength of the light is 500nm. (20 pts)
- a) What is the energy of each photon?

$$E = h\nu = \frac{hc}{\lambda} = 3.98 \times 10^{-19} \text{ J} \\ = 2.48 \text{ eV}$$

- b) What is the number of photons (per second)
- 1) entering the fiber,

$$200 \text{ mW} = \left(\frac{\#}{\text{s}} \right) \times E_{ph}$$

$$\frac{\#}{\text{s}} = 5.03 \times 10^{17} \frac{\text{Photons}}{\text{s}}$$

- 2) reaching a position that is 200.0m down the fiber?

$$\frac{\#}{\text{s}} = 5.03 \times 10^{17} e^{-1} = 1.85 \times 10^{17}$$

Bonus 5 pts: Determine the first positive solution to $\text{Tan}(x)=1/x$, show at least three table elements.

X	Tan(x)	1/x

0.84	1.115632	1.190476
0.85	1.138333	1.176471
0.86	1.161556	1.162791
0.87	1.185325	1.149425
0.88	1.209664	1.136364
0.89	1.234599	1.123596

