Exam #3

1) Compton Scattering. *3 Points*

In Compton scattering of X-rays from electrons the outgoing X-rays have shorter wavelength than the incoming X-rays: True or False.

Outgoing γ lower E $\Rightarrow$ longer λ

2) Bug fixing the Periodic Table. *6 Points*

Before Moseley, the periodic table was ordered by atomic mass. Mosley showed that it should be ordered by atomic charge. Describe how was he able to measure the charge on the nucleus Z.

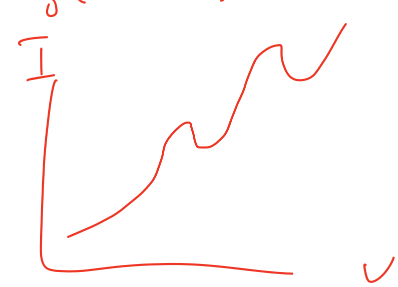
Mosely looked at the X-ray spectra when inner electrons are ejected from è's replaced by outer è's the ΔE according to the Bohr model depends on Z.

3) The Frank-Hertz Experiment. *7 Points*

Describe how the quantization of atomic energies can be observed by looking at electron collisions in gas.

If electrons are sent through a gas w/ varying Energy at first all scattering will be elastic when $E < \Delta E_{atom}$

Once the electron E is high enough will start seeing inelastic scattering



4) Cathode rays *10 Points*

Describe Thompson's Cathode-ray experiment that discovered the electron. What did property of electrons did he measure ? What was surprising about his result ?

Subjected Cathode-rays to $\vec{E}$ & $\vec{B}$ fields

measured the displacement of the beam.

This was sensitive to $\frac{q}{m}$.

The surprising result was that $\frac{q}{m}$ was very large

or if q same as Ion m very small.

5) Development of the Atomic model. *10 Points*

Describe Rutherford's experiment testing the atomic model. What was unexpected about his results ? How did this change our picture of the atom?

Shot α particles at thin gold foil.

Unexpected: Saw large angle scatterings.

His experiment killed the "Choc. chip cookie" model & implied something like the Solar System

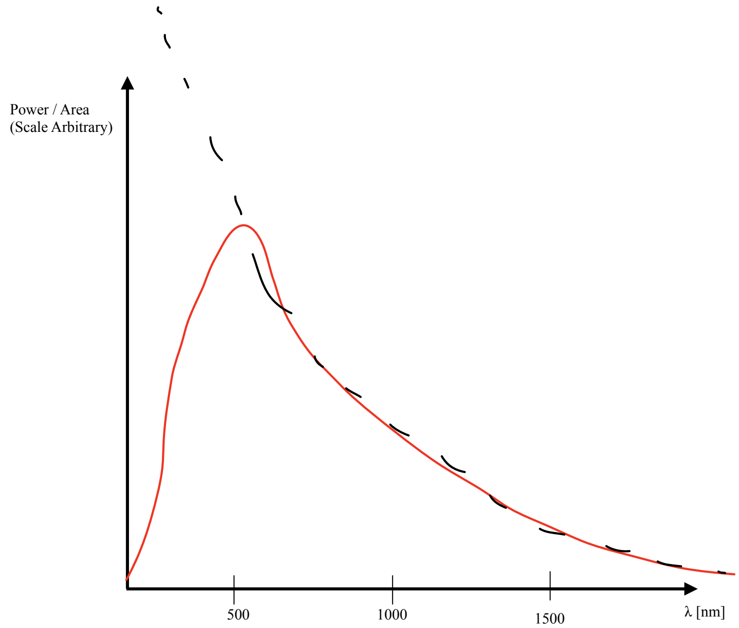
Small hard core nucleus.

$\lambda_m T \sim 3\,10^6$ Knm

$\lambda_m \sim \frac{3}{6}\,10^3$ nm $\sim$ 500 nm

6) Black body radiation *12 Points*

Sketch the observed radiation distribution (power radiated / unit area) vs wavelength for a black-body with temperature 6000 K. Overlay a sketch of the classical prediction.



In natural units, temperature has units GeV. What are the units of power/area in GeV? How does the total power output by a star (which is a blackbody) scale with temperature ?

$\frac{P}{A} \sim \frac{E}{S\,A} \sim GeV^4$ $\qquad P \sim T^4$

7) The Bohr Model of an Atom. *7 Points*

How was Bohr's model different from the planetary model of atoms that came before it ? What problems did the Bohr model address ?

Bohr assumes Stable non-radiating orbits

Stability of Atom & discrete λ's

8) Photoelectric Effect *(10 points)*

Suppose we are shinning a beam of ultraviolet light of known wavelength onto a metal surface with a binding energy of electrons (or work function) is 2.0 eV

a) If this light liberates photo-electrons of maximum kinetic energy 3.0 eV, what is the wavelength of the light?

$E_{KE} = E_\gamma - \phi \Rightarrow E_\gamma = 3 + 2 \text{ eV}$

$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{1240 \text{ eV nm}}{5} \sim 230 \text{ nm}$

b) Suppose the intensity of the light impinging upon the metal surface is tripled. What do you expect to happen to the number of electrons liberated from the surface? Explain.

Intensity tripled $\Rightarrow$ 3x number of e^-'s liberated

3x the γ's in, 3x the e^-'s out.

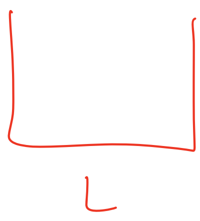
c) Suppose instead that the wavelength of the light is tripled. What do you expect to happen to the number of electrons liberated from the surface? Explain.

$\lambda \to 3\times\lambda \Rightarrow E_\gamma \to \frac{E}{3} = \frac{5}{3} \text{ eV} < 2$

No e^-'s out!

9) Particles As Waves *15 Points*

a) Use the uncertainty principle to estimate the energy of an electron in an infinite square well of width L.



$\Delta x \sim L$ $\qquad E \sim \frac{p^2}{2m} = \frac{1}{2mL^2}$

$\Delta p \Delta x \sim 1$

$\Delta p \sim \frac{1}{\Delta x} \sim \frac{1}{L}$

b) Use the uncertainty principle to estimate the size of a hydrogen atom (V = $-\alpha/r$). *(Express your result in terms of m_e. α)* Do you need to worry about relativistic effects when analyzing the Hydrogen atom ? Justify your answer.

$E = \frac{p^2}{2m} - \frac{\alpha}{r}$ $\qquad p \cdot r \sim 1$

$E = \frac{1}{2mr^2} - \frac{\alpha}{r} \Rightarrow \frac{1}{2mr^2} \sim \frac{\alpha}{r}$ or $r = \frac{1}{m_e \alpha}$ $\qquad$ non-rel ok

$\Rightarrow p = m_e \alpha$

or $v = \alpha \ll 1$

c) Use the uncertainty principle to estimate the size of a muonium atom. Muonium is the bound state of a muon (m=0.1 GeV) and a proton. Do you need to worry about relativistic effects when analyzing Muonium ? Justify your answer.

Same as above $\quad m \to \mu = \frac{m_p m_\mu}{m_p + m_\mu} = \frac{m_\mu}{1 + 0.1} \sim m_\mu$ ✓

$r \sim \frac{1}{m_\mu \alpha}$ $\qquad v \sim \alpha$ non-rel Ok