Last Week

Last Question:
Why did you see the colors of the rainbow when white light shined through a diffraction grating?
Interference Pattern, Red Light

Let’s shine a laser on the grating and consider the first bright spot, \( m=1 \). (Remember the grating and double slit patterns follow the same math.)

\[
d \sin \theta = \lambda \\
\sin \theta = \frac{\lambda}{d}
\]
Interference Pattern, Blue Light

Now let’s use a blue laser.

Why is the angle reduced?

\[ d \sin \theta = \lambda \]

\[ \sin \theta = \frac{\lambda}{d} \]
Interference Pattern, White Light

We can assume that white light is a mixture of all colors; therefore it is a mixture of all wave lengths.

\[ d \sin \theta = \lambda \]
\[ \sin \theta = \frac{\lambda}{d} \]
Radioactivity

• In 1896, Henri Becquerel, while investigating fluorescence in uranium salts, accidentally discovered radioactivity.

• Work by Curies and others showed that radioactivity was the result of the decay or disintegration of unstable nuclei.

• Up to that point, atoms were believed to be forever indestructible.
Radiation

Types

• Alpha particles are helium nuclei (2 p, 2 n):

• Beta particles are speedy electrons:

• Gamma radiation is a stream of photons:
Example 1: Alpha Decay

\[ \begin{align*}
A_X & \rightarrow A-4_{Z-2} Y + {}^4_2 \text{He} \\
226_{88} \text{Ra} & \rightarrow 222_{86} \text{Rn} + p_{\alpha}
\end{align*} \]

- X is called the parent nucleus and Y the daughter nucleus.
- Example is Radium, decaying into Radon and an alpha particle.
- In order for alpha emission to occur, mass of the parent must be greater than combined mass of daughter and alpha particle.
  - Excess mass converted into kinetic energy, most of which is carried by the alpha particle.

\[ KE_{\text{Ra}} = 0, \quad p_{\text{Ra}} = 0 \]

Before decay

\[ KE_{\text{Rn}}, \quad p_{\text{Rn}} \]

After decay

\[ KE_{\alpha}, \quad p_{\alpha} \]

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Example 2: Beta Decay

\[ _Z^A X \rightarrow _{Z-1}^A X + e^- \]

**Example**

A neutron turns into a proton emitting an electron

\[ _0^1 n \rightarrow _1^1 p + e^- \]
If a radioactive sample contains N radioactive nuclei at some instant, the number of nuclei that decay in a time $\Delta t$ is proportional to N:

- $\Delta N/\Delta t \propto N$
- $\Delta N = -\lambda N \Delta t$
- where $\lambda$ is a decay constant

$R = |\Delta N/\Delta t| = \lambda N$
- rate of which atoms decay

$N = N_0 e^{-\lambda t}$

$T_{1/2}$ (half-life) is time it takes for half of sample to decay.

Decay constants vary greatly for different radioactive decays and thus so do half-lives.
Radioactive Dating

We can often use radioactivity to measure the age of an object. Consider $^{14}$C dating.

- Cosmic ray interactions in the upper atmosphere cause nuclear interactions that produce $^{14}$C from $^{14}$N.
- Living organisms breathe in carbon dioxide that has both $^{12}$C and the radioactive $^{14}$C.
- So all living creatures have the same ratio of $^{14}$C to $^{12}$C ($\sim 1.3 \times 10^{-12}$).
- When the organism dies, however, it no longer absorbs carbon dioxide from the air, and so the ratio of $^{14}$C to $^{12}$C decreases.

\[ ^{14}_{12}\text{C} \rightarrow ^{14}_{7}\text{N} + \text{e}^- + \nu \]

The greater the value of $^{14}$C / $^{12}$C, the more recently the organism died.
Carbon-14 Dating

Works on samples from about 1 to 25,000 years old.

→ Why not longer?

→ The half-life of $^{14}$C is 5730 years. After about 5 half-lives too small a fraction of $^{14}$C is left ($2^5=32$ so $<1/32$nd left).

Example:
Dead Sea Scrolls date to 1950 years ago
Geiger Counter

- Device used to detect ionizing radiation
- Consists of a tube filled with Argon gas with a central wire at a high voltage
- When a charged particle passes through the gas, it knocks electrons off of the Argon atoms
- The electrons are attracted to the positively charged central wire and are accelerated towards it
- They acquire enough energy to knock more electrons off of Argon atoms
- The result is an avalanche of electrons hitting the central wire which creates an electronic signal
Final Exam
Format and suggested review material

General Information
The final exam will take place during the last class, April 23rd, at the regular class time of your section. The exam will be “closed book”. It is intended to be a 45 minute exam. However, you will be given as much as 90 minutes to complete it.

Formula Pages
The exam will contain a list of useful constants and formuli. In addition you may bring your own formula pages – up to two 8.5” x 11” sheets. The front and back of each page may contain formulas or any background information. *The material must be handwritten.*
Final Exam

Exam Format
The exam will consist of approximately 24 problems. About half of the problems will be multiple choice or true/false. Some of these problems will be very similar to quiz questions. About half of problems will require calculations, similar to ones performed in the labs.

Suggest Review Material
Material that was covered during the introductory lectures and during the lab itself are fair game for the final exam. Recommended material to review:
(1) The introductory lectures
(2) The main physics ideas and the main calculations that were performed for each lab
(3) The quizzes
Final Exam

Make sure you have all the material
If you have misplaced any of the returned lab reports and quizzes, I would urge you to photocopy the material from a classmate.

Grading
The final exam will be 20% of the course grade. The course grades will be determined on an absolute scale as described in the course syllabus.