PHYS 214 Exam 2 Review

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Welcome to the … n!

Exam Review 1:

- Tuesday, 2

Worksheet

Solutions

Slides

Additionally, he … at may help you on your test. If you don't have Jupyter on your computer, you can open th

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Good luck on yo

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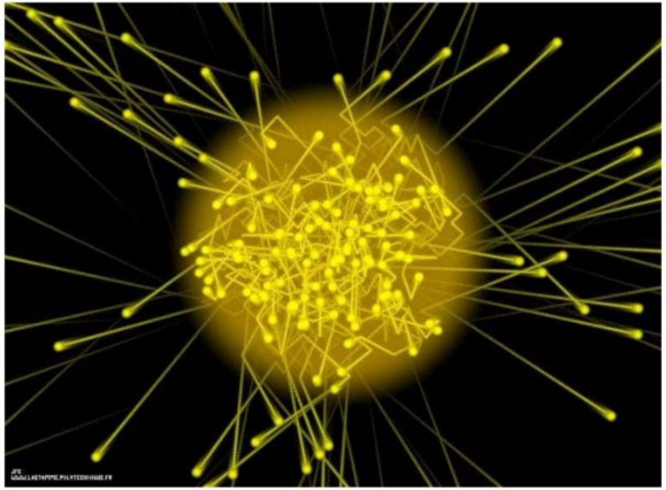
Units Covered on Exam 2

- Unit 4: Photons
- Unit 5: Probability and Complex Numbers
- Unit 6: The Wave Function
- Unit 7: Momentum and Position

Photons



Photons: the quantized bits of light (particles of light)

- Energy of a single photon with frequency *f*:

$$E = hf = \hbar\omega = \frac{1240 \text{ eV nm}}{\lambda}$$

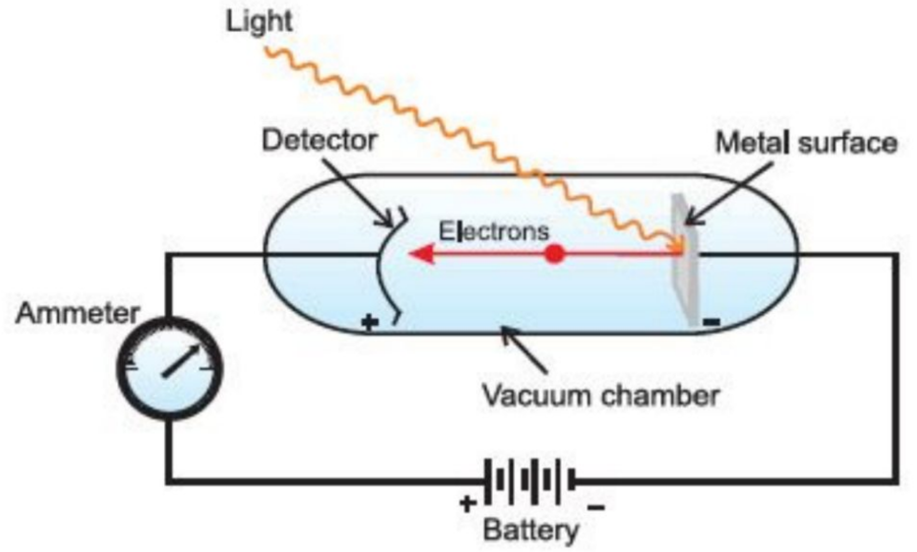
- Momentum of a single photon with wavelength λ:

$$p = \hbar k = h/\lambda$$

- $h = 6.626 \times 10^{-34}$ J · s
- $\hbar$ ('h-bar') = $h/2\pi$

- Photons have a velocity of c:
  - $c = 3*10^8$ m/s
  - $c = \lambda f \longrightarrow E = (hc)/\lambda$

The Photoelectric Effect



The Photoelectric (Cont.)

This experiment proves the existence of photons and that light can be **BOTH** a particle and a wave

$$KE_{\text{electron}} = eV_{\text{stop}}$$

Stopping Potential: Voltage applied to stop electrons from flowing between the two plates

Work Function (property of the material the light is shining on)

$$KE_{\text{electron}} = hf - \Phi$$

Maximum Kinetic Energy of an ejected electron

Planck's constant times frequency of incoming photons (light)

Effect of Power Source

Increasing the power of a photon source will <u>NOT</u> increase photon energy!

It will only increase photon flux, since frequency/wavelength is what determines photon energy

$$\frac{\#\text{ photons}}{\text{sec}} = \frac{P\text{ Joules}}{\text{sec}} \times \frac{1\text{ photon}}{X\text{ Joules}}$$
$$\text{where } X = hf = hc/\lambda$$

Force from Photons

$$F = \frac{dp}{dt} = \frac{momentum}{second}$$

$$\frac{momentum}{second} = \frac{P\ joules}{second} * \frac{1\ photon}{hf\ joules} * \frac{\frac{h}{\lambda}\ momentum}{1\ photon}$$

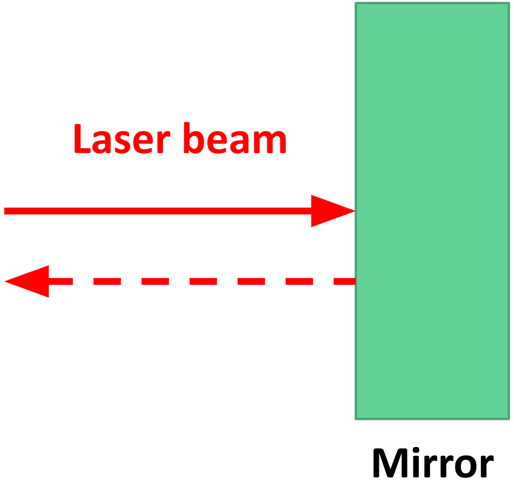
photons/second

Simplified → F = P/(λf) = P/c

Example Problem - Photons & Mirrors

A perfectly reflecting mirror is illuminated by a laser beam with a power of **10 mW** and wavelength of **500 nm**.

Determine the force exerted on the mirror by the photons



Example Problem - Photons & Mirrors (Cont.)

$$F = \frac{dp}{dt}$$

Example Problem - Photons & Mirrors (Cont.)

$$F = \frac{dp}{dt}$$

$$F = \frac{2P}{c} = \frac{2(10 * 10^{-3})}{3 * 10^{8}} = 66.67\ pN$$

Example Problem - Photons & Mirrors (Cont.)

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Probability and Complex Numbers

Probability

- Probability Density Function:

$$\rho(x)$$

- Probability between two points:

$$P(a \leq x \leq b) = \int_a^b \rho(x)\,\mathrm{d}x$$

- Normalization:

$$\int_{-\infty}^{\infty} \rho(x)\,\mathrm{d}x = 1$$

Complex Numbers

- Two forms:

$$z = a + bi = |z|e^{i\theta}$$

- Conversion:

$$\theta = \arctan(b/a) \quad z = |z|(\cos\theta + i\sin\theta)$$

- Magnitude Squared:

$$|z|^2 = (z^*)(z)$$

- Identities:

$$\cos\theta = \frac{e^{i\theta} + e^{-i\theta}}{2} \quad \sin\theta = \frac{e^{i\theta} - e^{-i\theta}}{2i}$$

The Wave Function

- Wave function is notated as **Ψ(x)**
  - Contains **ALL** information about the properties of a quantum particle

- Properties of **Ψ(x):**

$$\rho(x) = \psi^*(x)\psi(x) = |\psi(x)|^2$$

Ψ*(x) is the complex conjugate of Ψ(x)

$$P(a \leq x \leq b) = \int_a^b (\Psi^*)(\Psi)\,\mathrm{d}x$$

Probability of detecting a particle between points a and b

Example Problem - Detection Probability

Given the following normalized wavefunction, what is the integral that gives the chance of measuring the particle in the range $|x| \leq 1$?

$$\Psi(x) = \frac{1}{\sqrt{2}} e^{-|x|/2}$$

Example Problem - Detection Probability (Cont.)

$$P(|x| \leq 1) = \int_{-1}^{1} \left(\frac{1}{\sqrt{2}} e^{-|x|/2}\right)^2 dx = \int_{0}^{1} e^{-x} dx \approx 0.63$$

Momentum and Position

- For particles with momentum **p = ℏk**, they are described by this wave function:

$$\psi(x) = Ae^{ikx}$$

→ **Momentum eigenstate (1 possible momentum)**

- Some particles' wave functions are a superposition of momentum eigenstates:

$$\psi(x) = \boxed{Ae^{ik_1x}} + \boxed{Be^{ik_2x}}$$

1st eigenstate **2nd eigenstate**

Momentum and Position (Cont.)

- Probability of each momentum is given by:

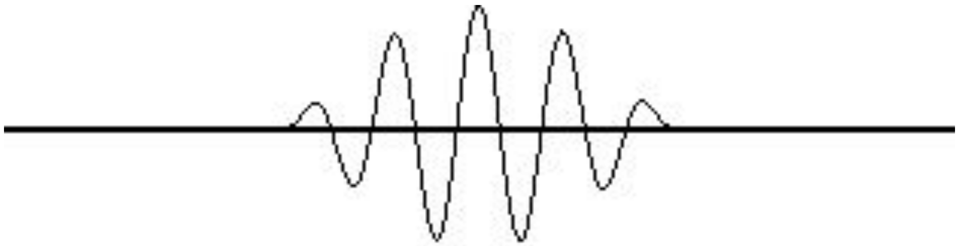
$$P(\hbar k_1) = |A|^2/(|A|^2 + |B|^2)$$
$$P(\hbar k_2) = |B|^2/(|A|^2 + |B|^2)$$

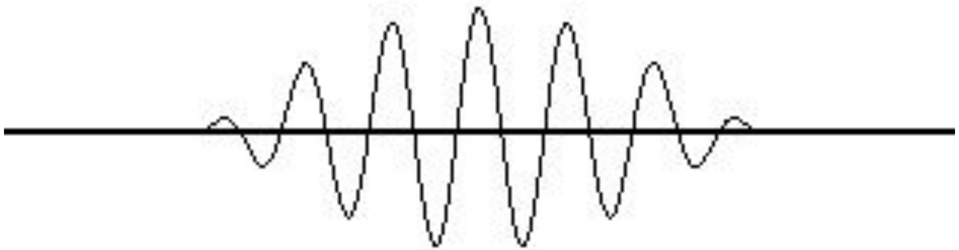
- Where A and B are the coefficients seen in the wave function: $\psi(x) = \underline{A}e^{ik_1x} + \underline{B}e^{ik_2x}$

- Overall uncertainty is given by **Heisenberg's Uncertainty Principle:**
- The **fewer** momentum eigenstates, the more certain we are for momentum
- The **more** momentum eigenstates, the more certain we are for position

$$\Delta x \Delta p \geq \frac{\hbar}{2}$$

Momentum and Position (cont.)





$$\Delta x \Delta p \geq \frac{\hbar}{2}$$

Example Problem - Probability of $\hbar k_1$

Determine the probability of the momentum given by $\hbar k_1$:

$$\psi(x) = 2ie^{ik_1x} + 3e^{ik_2x}$$

Example Problem - Probability of $\hbar k_1$ (Cont.)

$$P(\hbar k_1) = \frac{|2i|^2}{|2i|^2 + |3|^2} = \frac{4}{4+9} = \frac{4}{13}$$

Good luck on your exam!

Solutions will be posted at the end of the session. Feel free to ask us questions on homework and practice exams as well!